
Status of the 4pi Full-Volume Calibration System

The 4pi Group

4 π Group

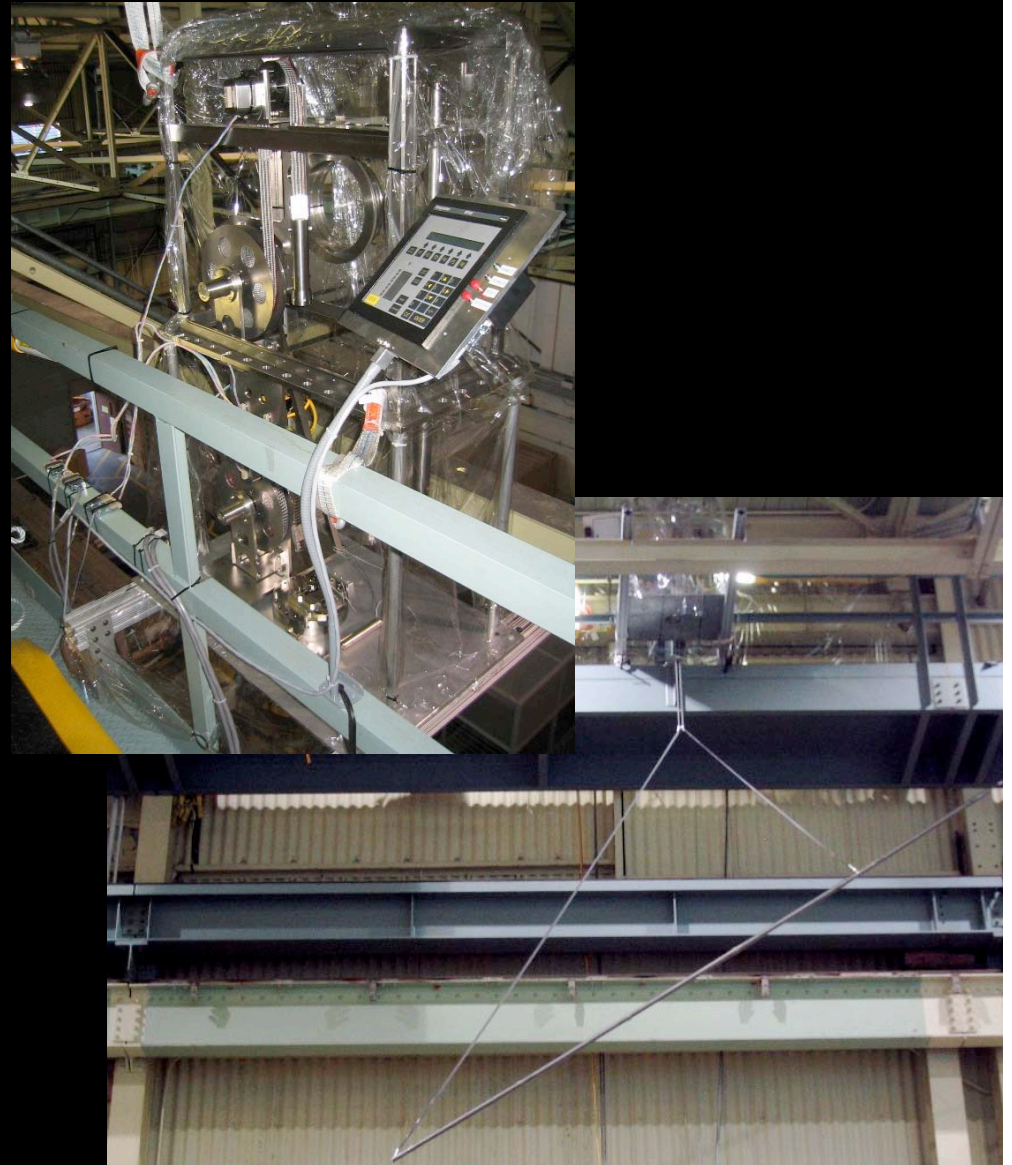
S. Abbott
B. Berger
T. Classen
P. Decowski
D. Dwyer
A. Franck
S.J. Freedman
B. Fujikawa
M. Galloway
F. Gray
K.M. Heeger
G. Keefer
J. Meyer
J. Learned
K.-B. Luk
C. Mauger
Y. Minamihara
B. Perry
M. Rosen
H. Steiner
D. Syversryd
E. Yakoushev
T. Walker
J. Wallig
L. Winslow

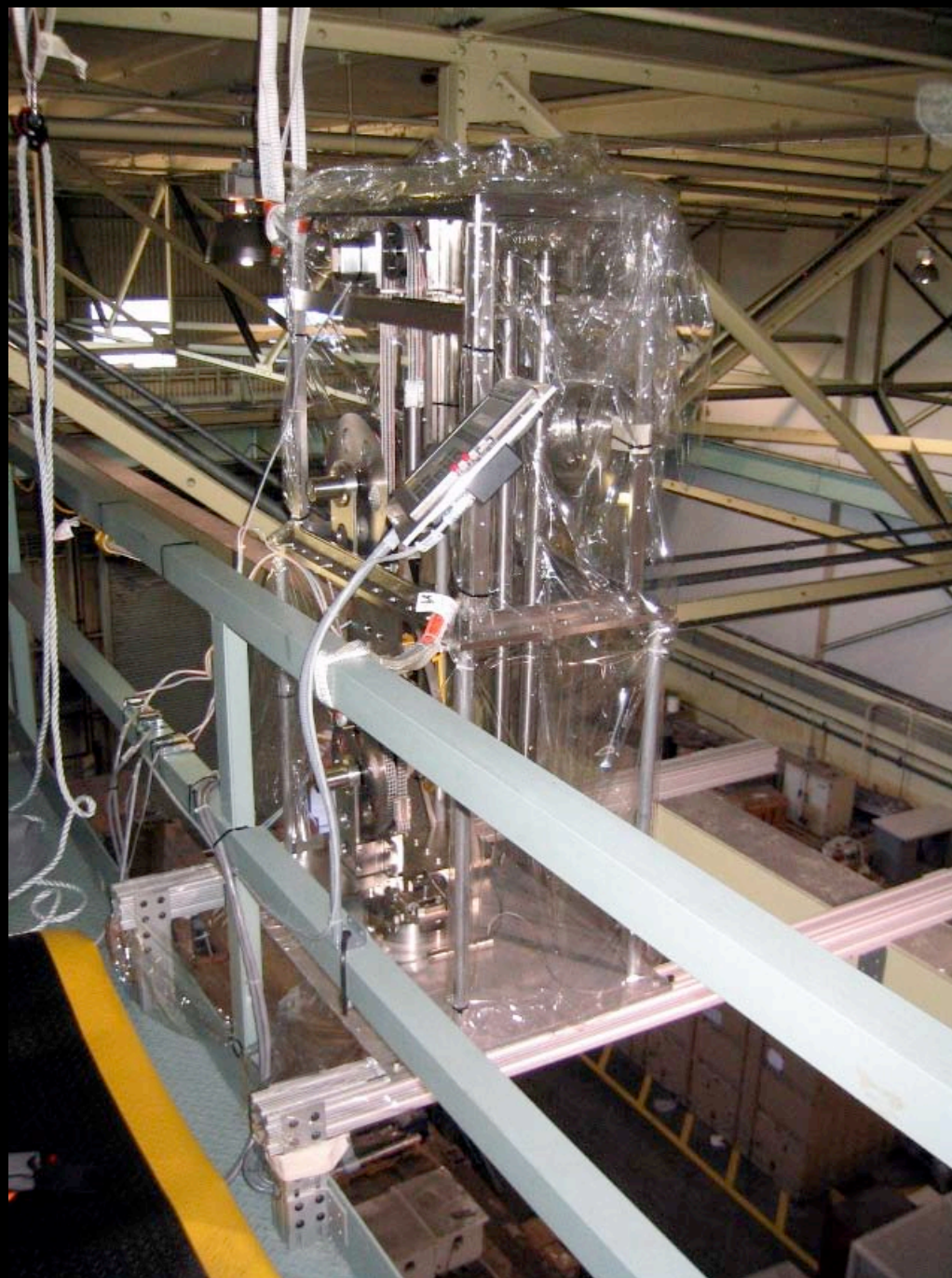
<http://kmheeger.lbl.gov/kamland/4pi/>

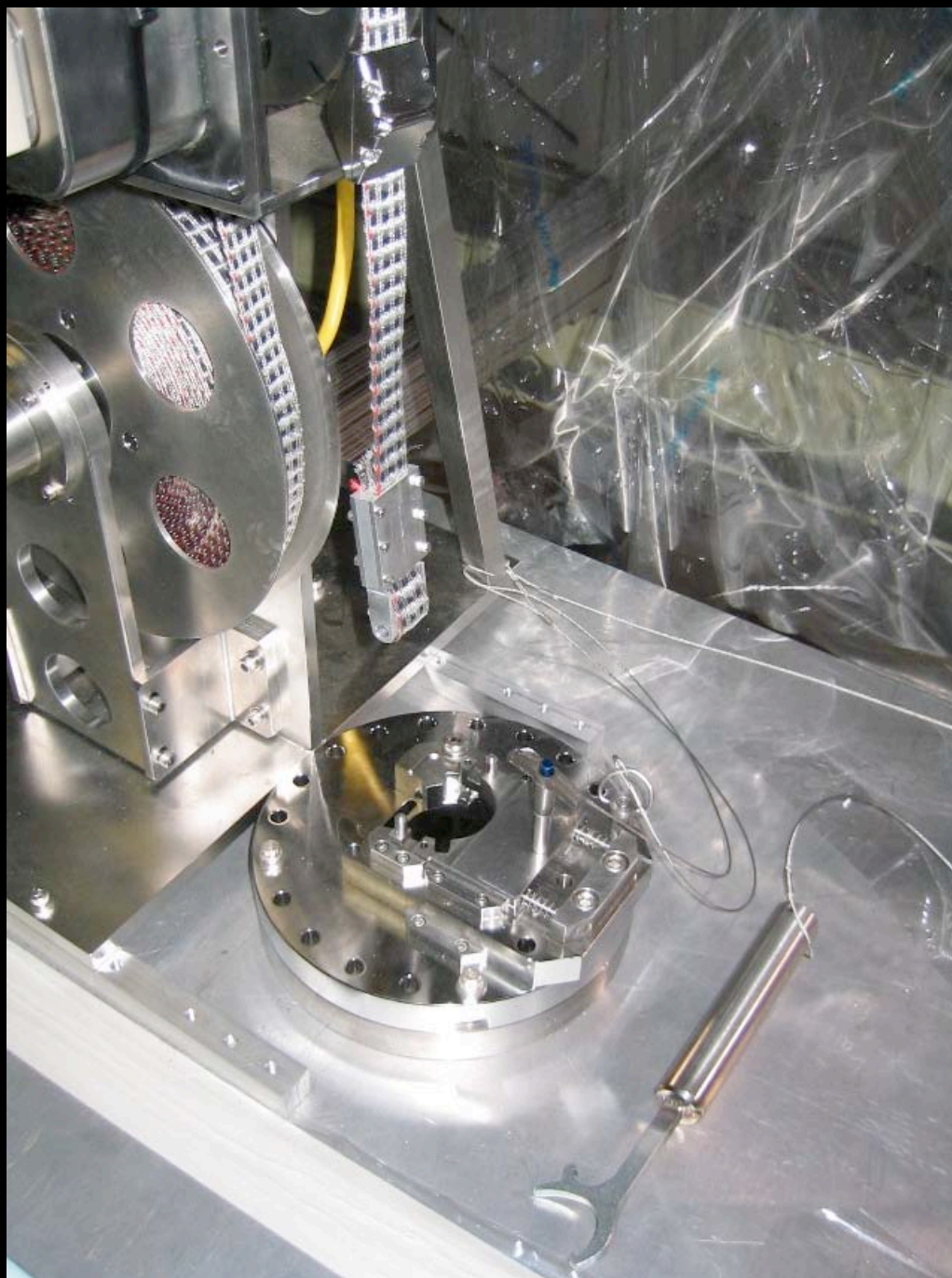
March 1, 2003
The “coat hanger” idea

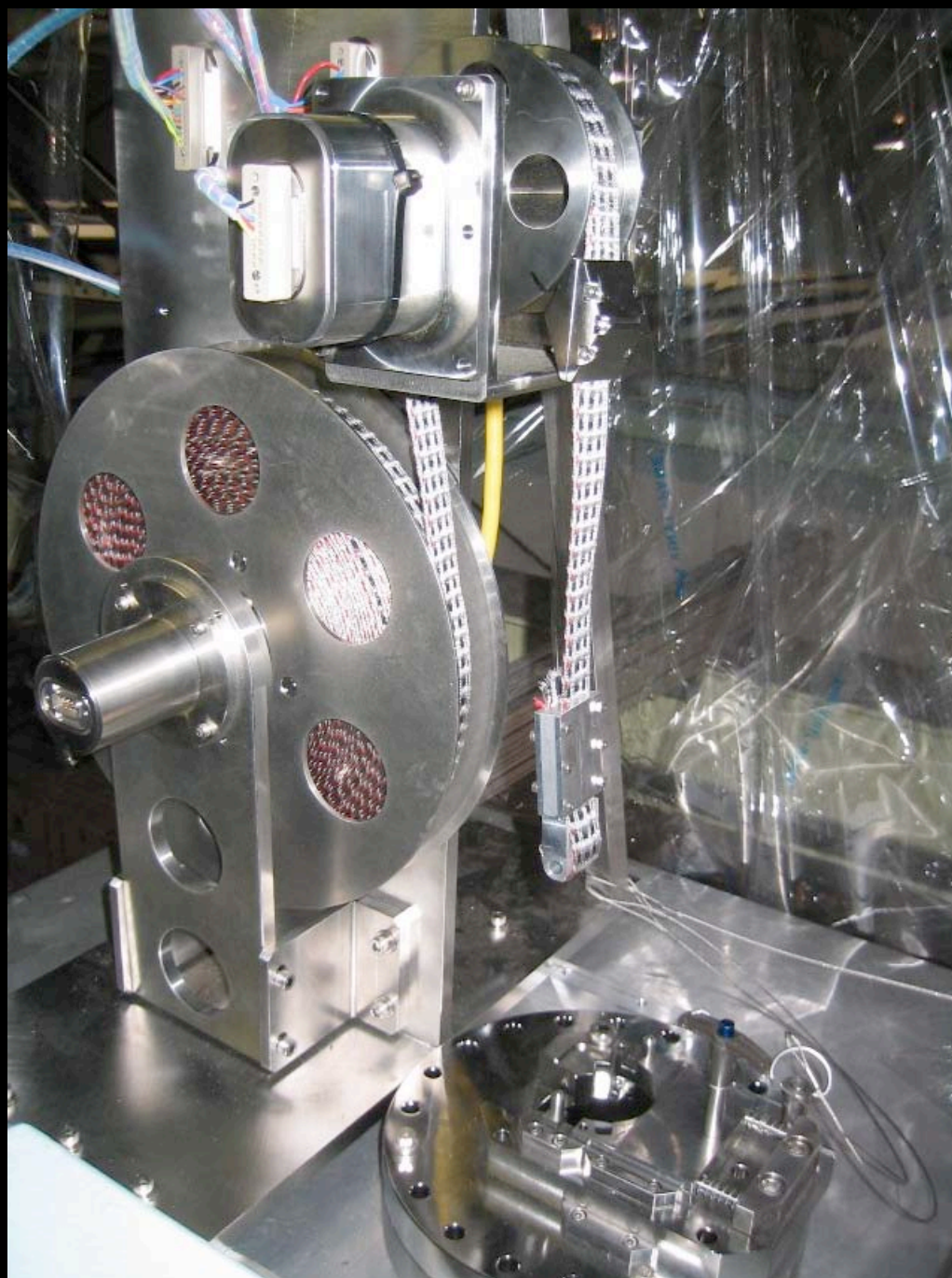


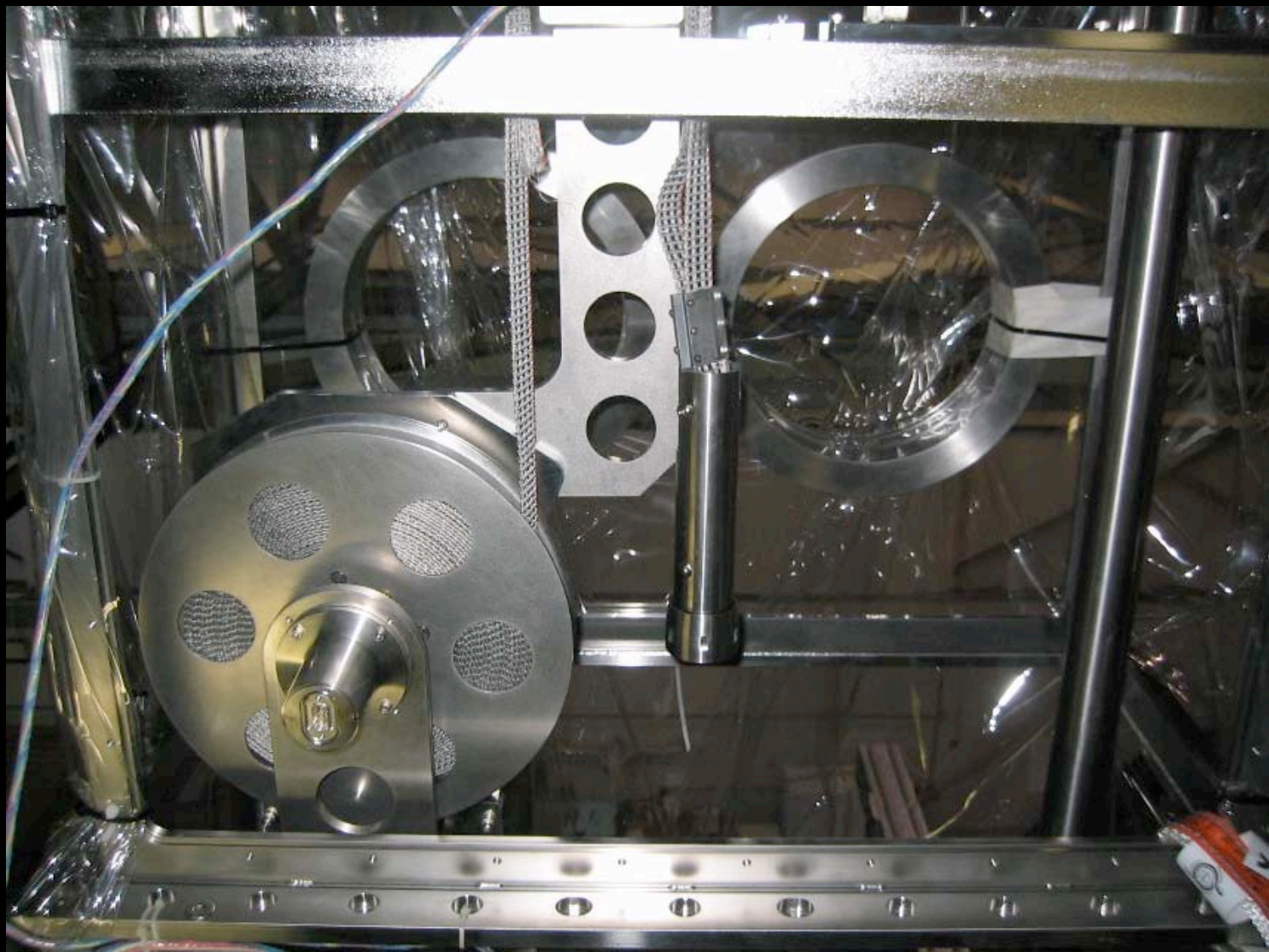
September 16, 2004
Full test of deployment system





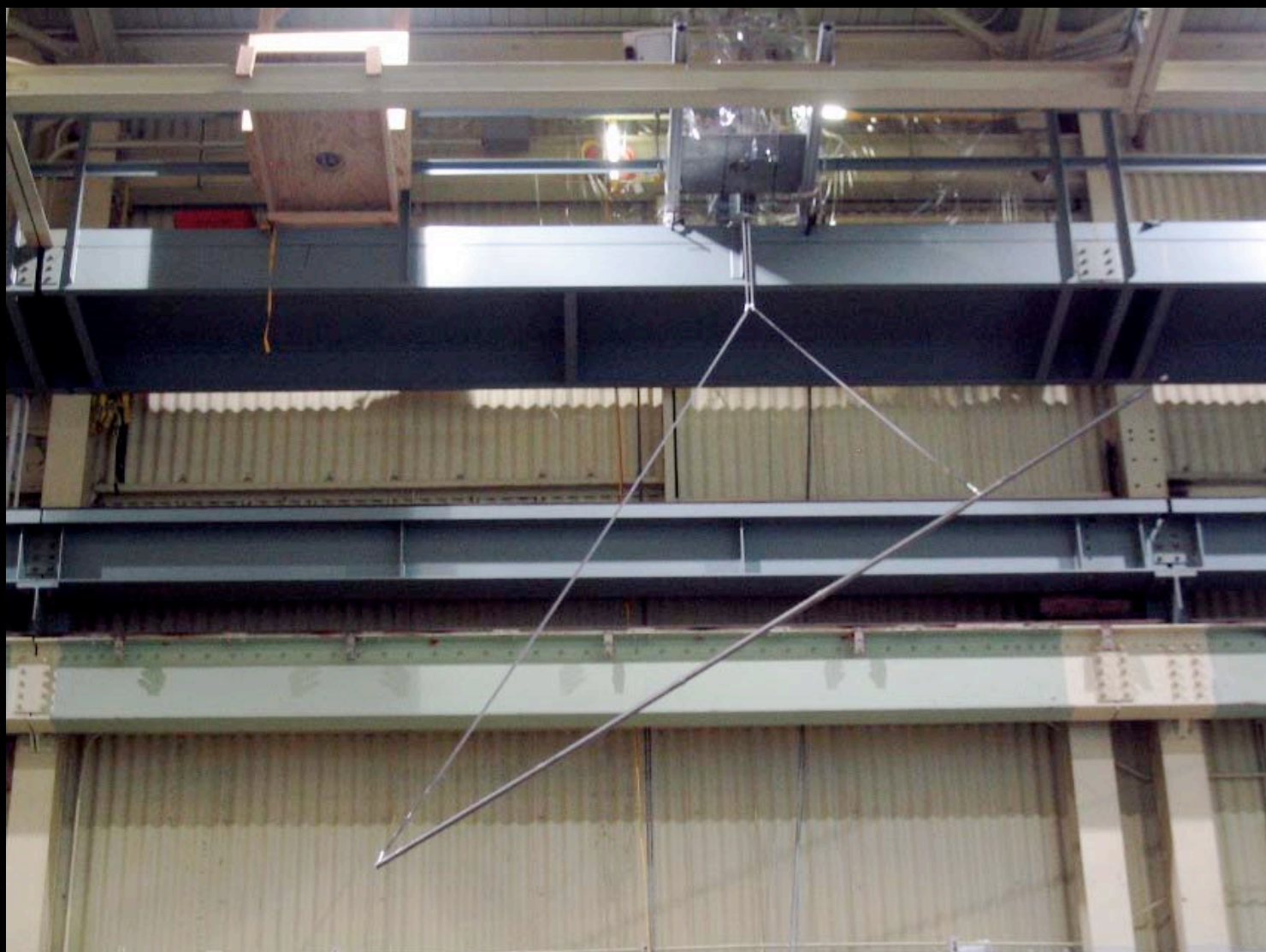




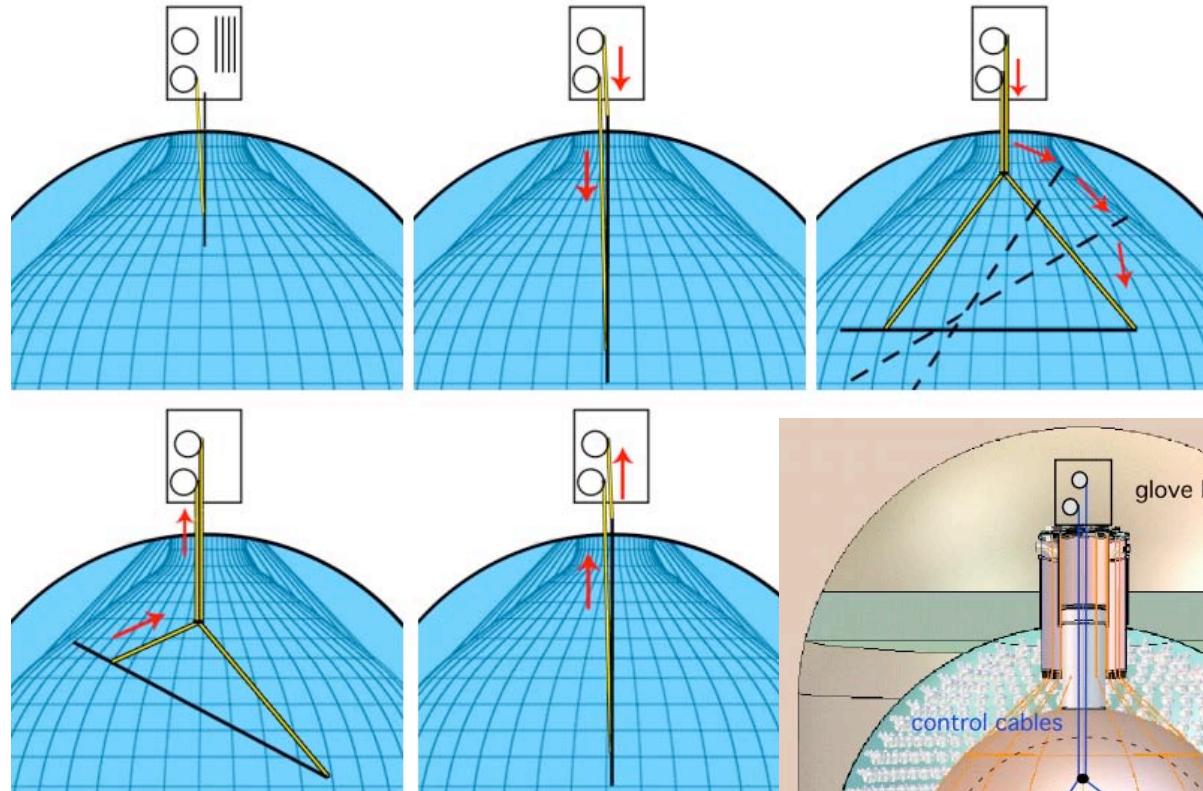








Calibration throughout entire detector volume



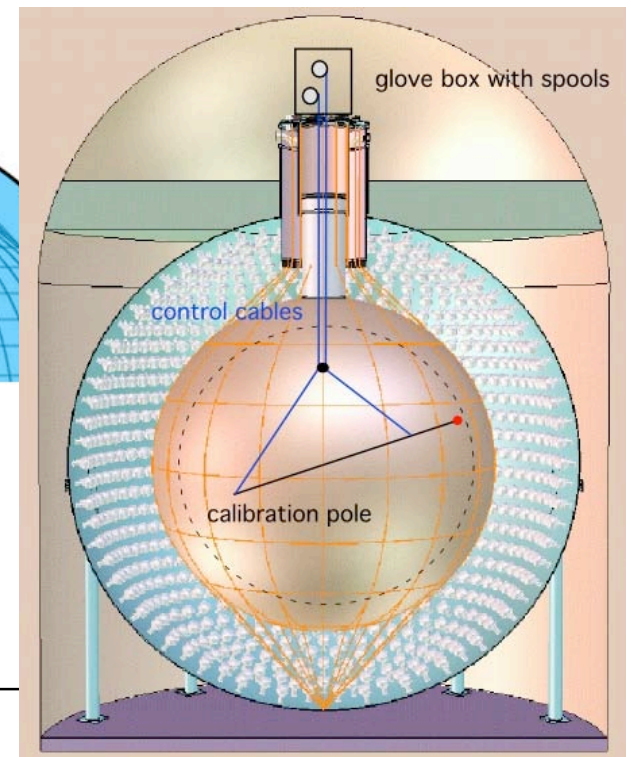
Fiducial volume:
 $R < 5.5$ m

$$\Delta R_{FV} = 5 \text{ cm} \\ \rightarrow \Delta V = 3\%$$

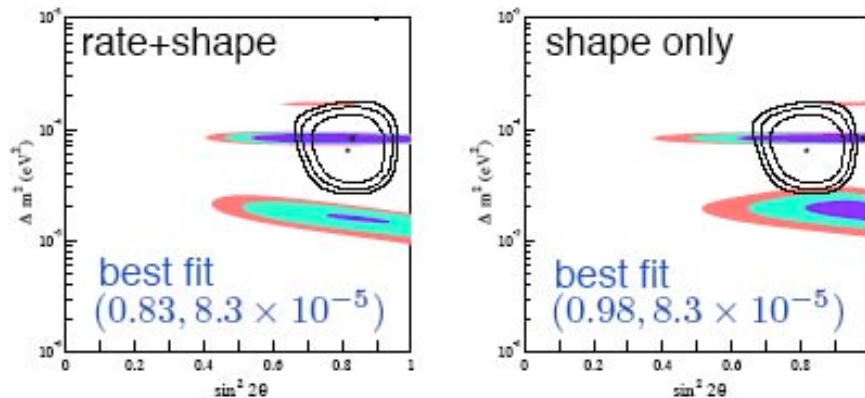
Position Dependence of Detector Response

Vertex reconstruction
Event energy

$$R_{\text{fit}}(r, \theta, \phi) \\ E(r, \theta, \phi)$$



Further improvement of systematic errors



Rate information doesn't have a strong impact on the precision due to large systematic errors.

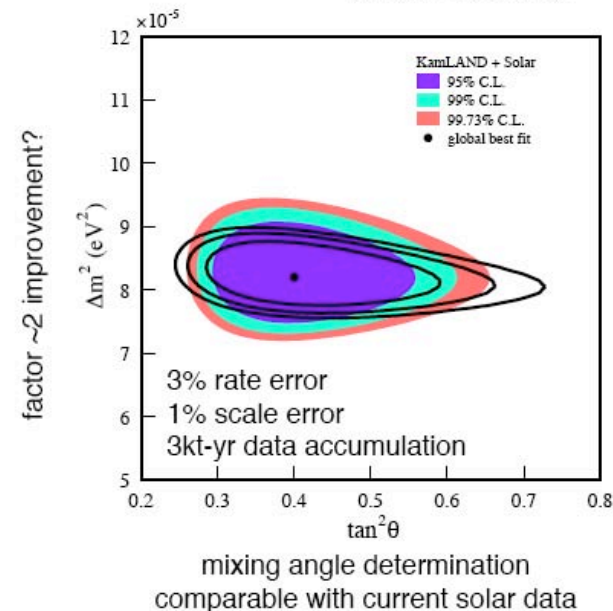
- KamLAND reactor result systematics limited:

fiducial volume
detector response

- KamLAND will make most precise determination of Δm_{12}^2 for the foreseeable future.

Inoue at NOW2004

KamLAND only rate+shape sensitivity (rough estimation)



capability to reject full mixing

Off-Axis Calibration System

I. Hardware

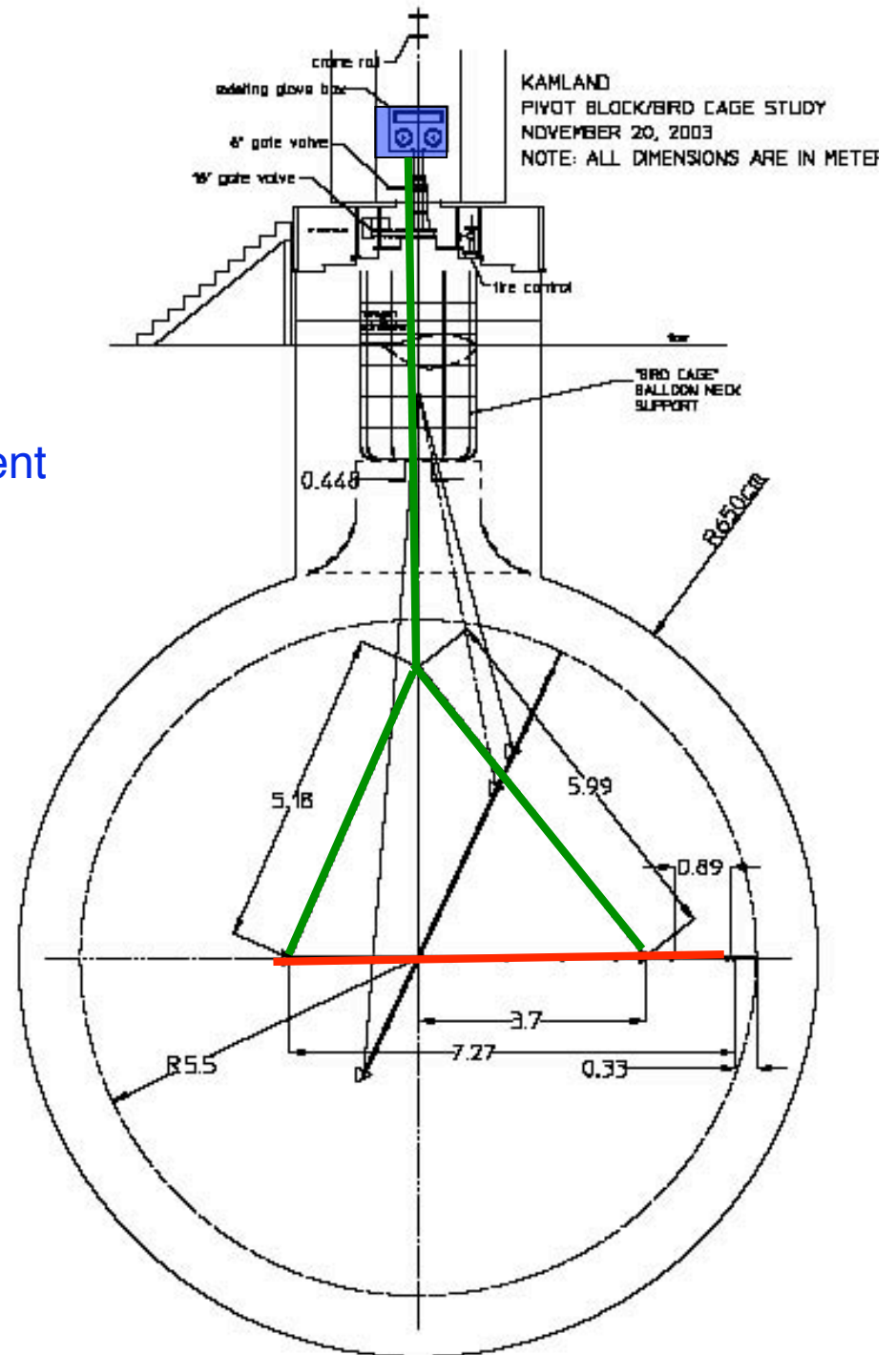
Glovebox System and Deployment Hardware

Control Cable + Pivot Block

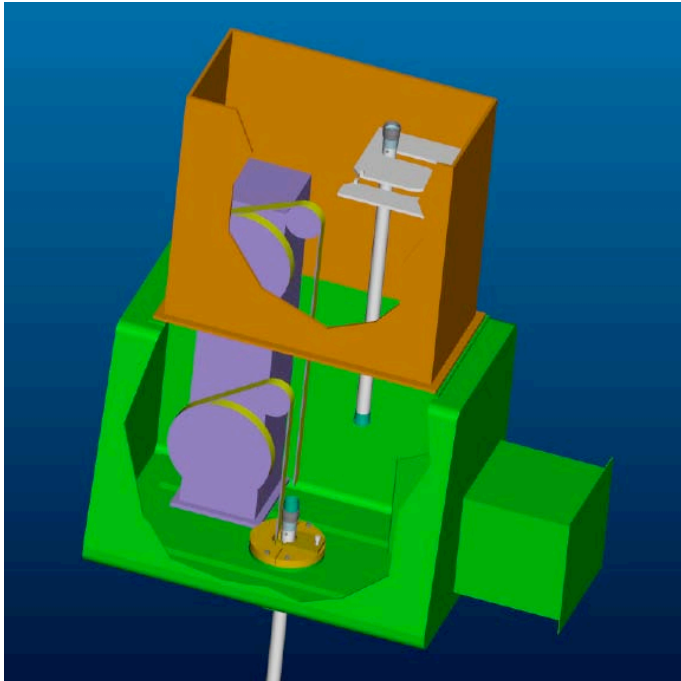
Calibration Pole

II. System Control Software

III. Position Reconstruction



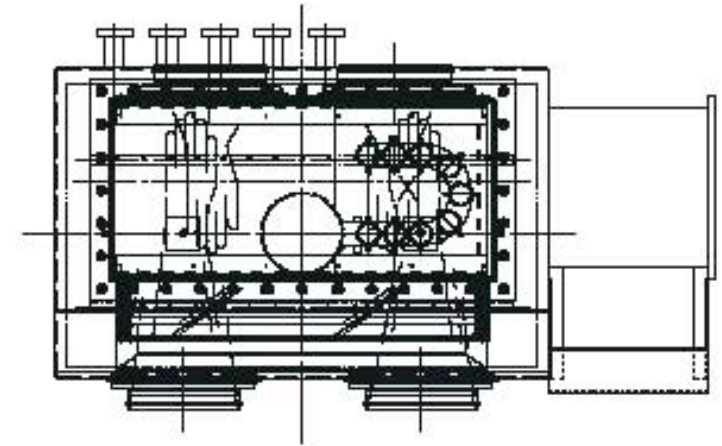
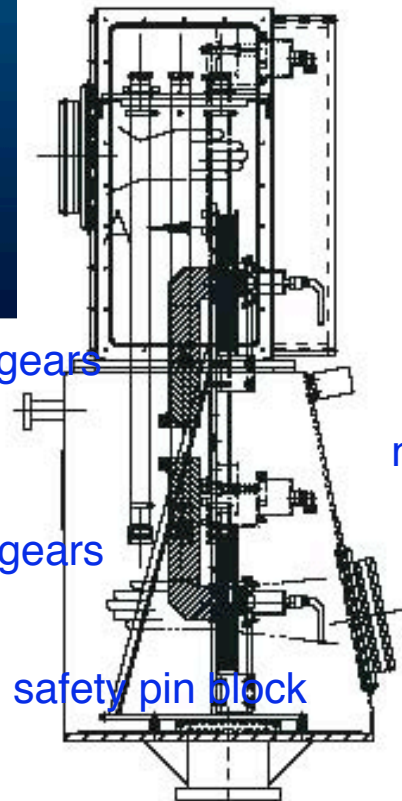
Glovebox System and Deployment Hardware



motors + gears

motors + gears

safety pin block



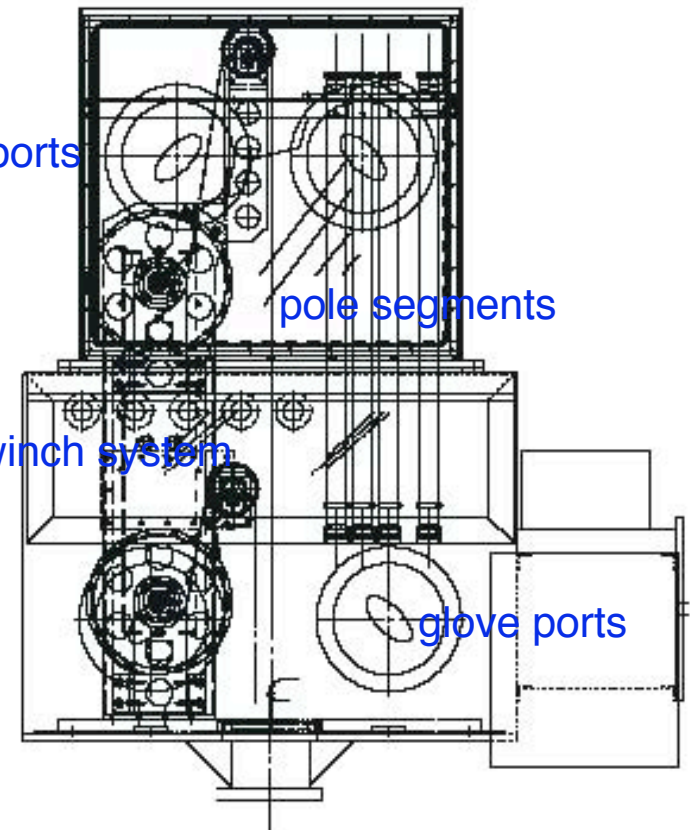
glovebox extension - penthouse

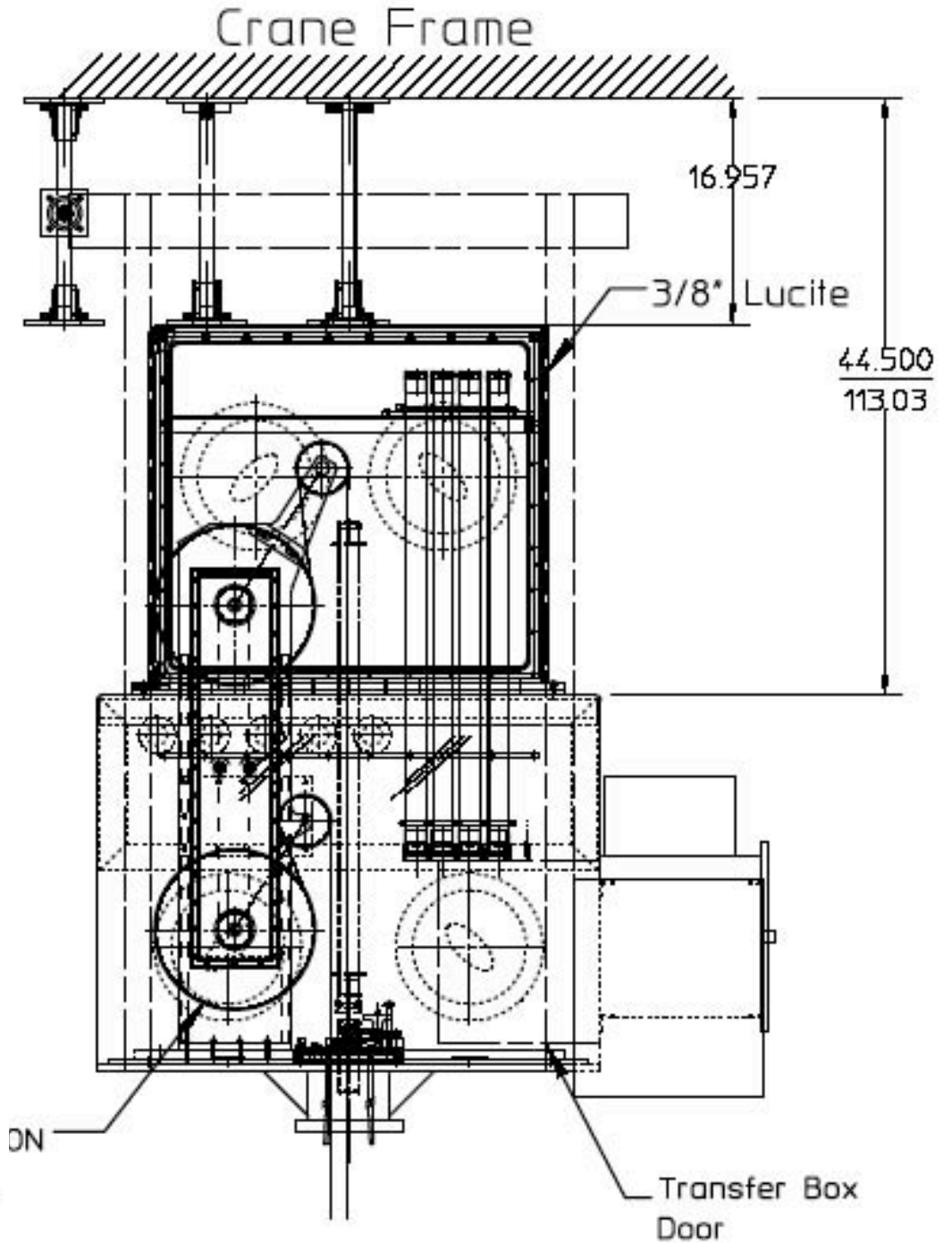
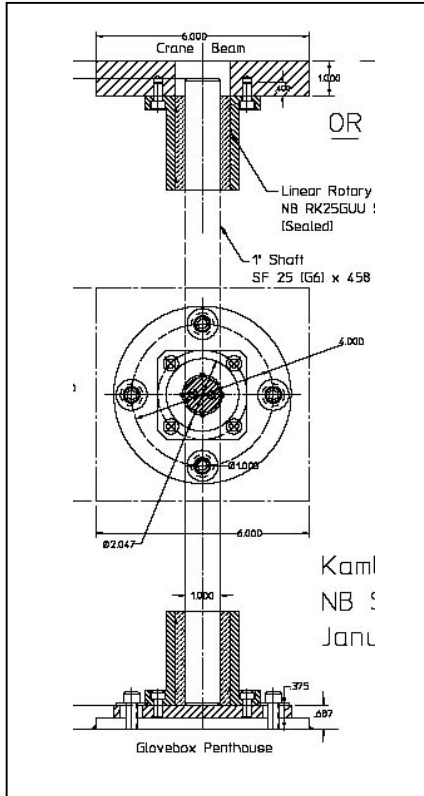
glove ports

pole segments

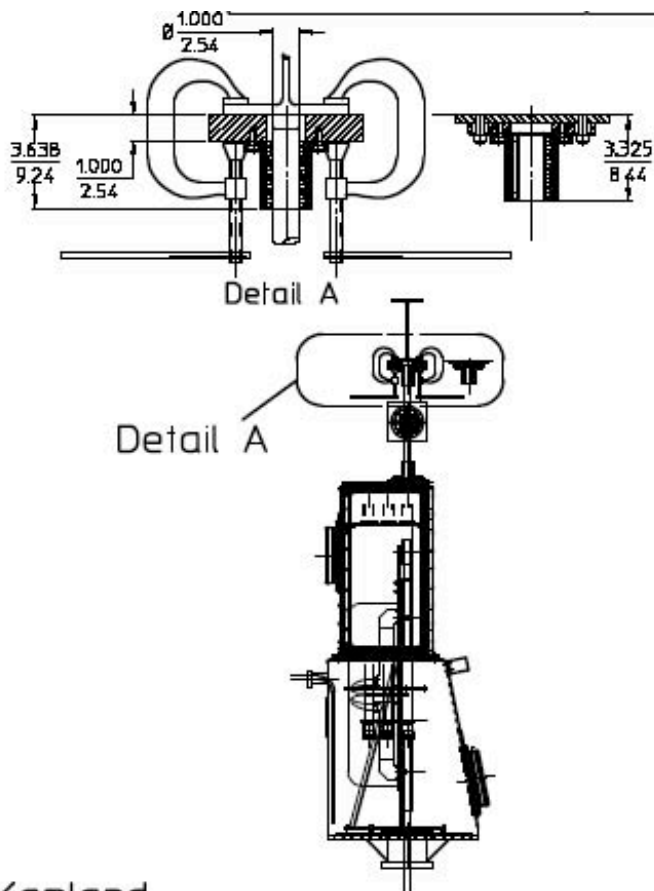
motor winch system

glove ports





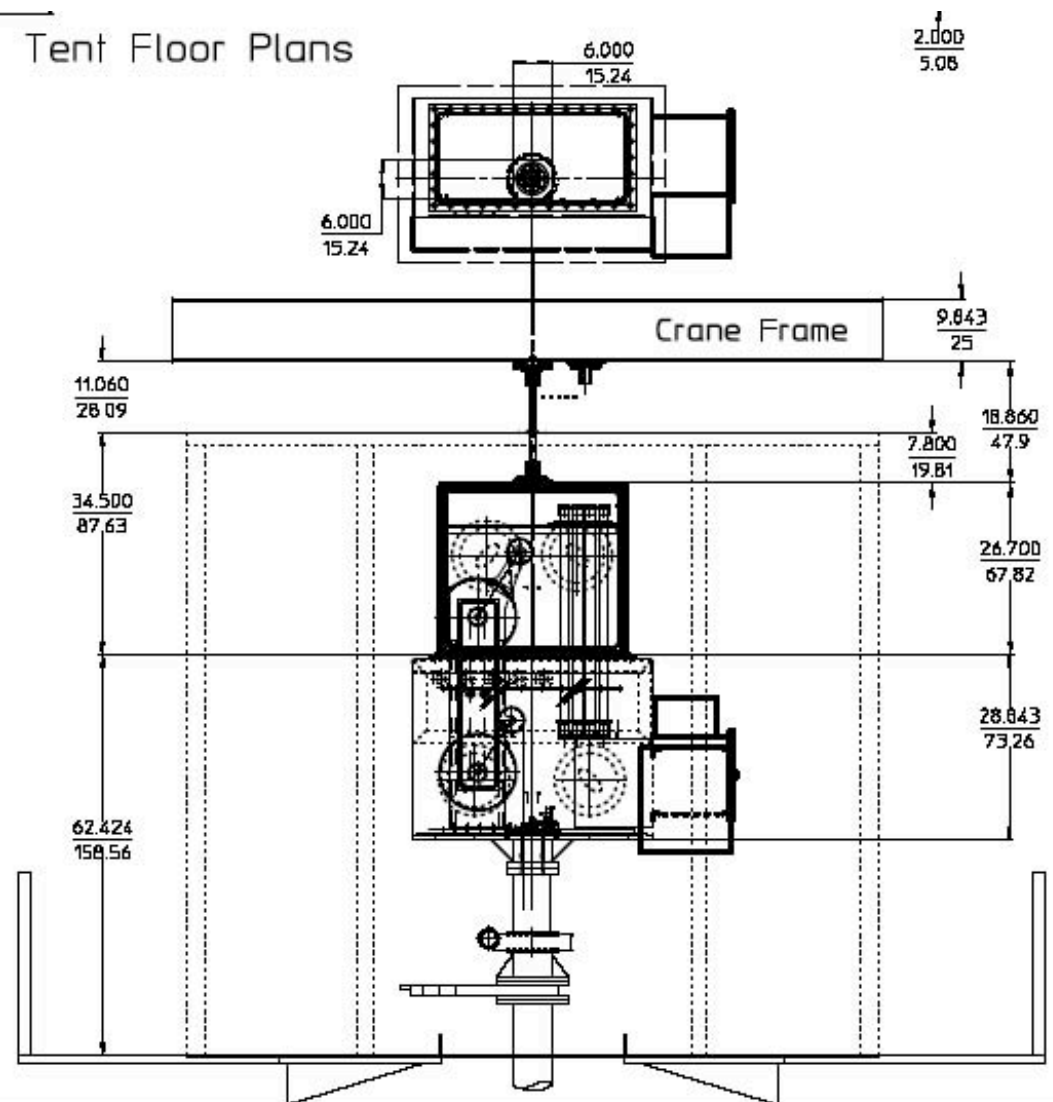
Glovebox Axial Support



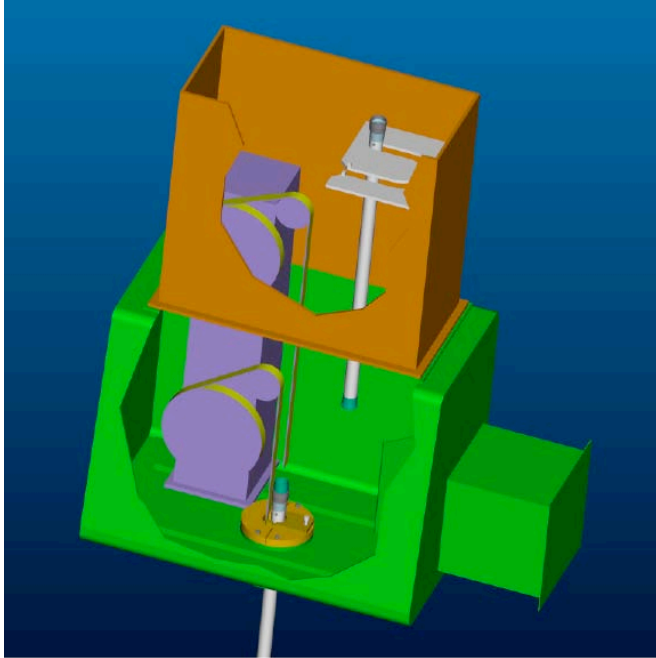
Kamland
Glovebox Support Bearing Layout
January 20, 2004

Note: All dimensions are in inches over centimeters.

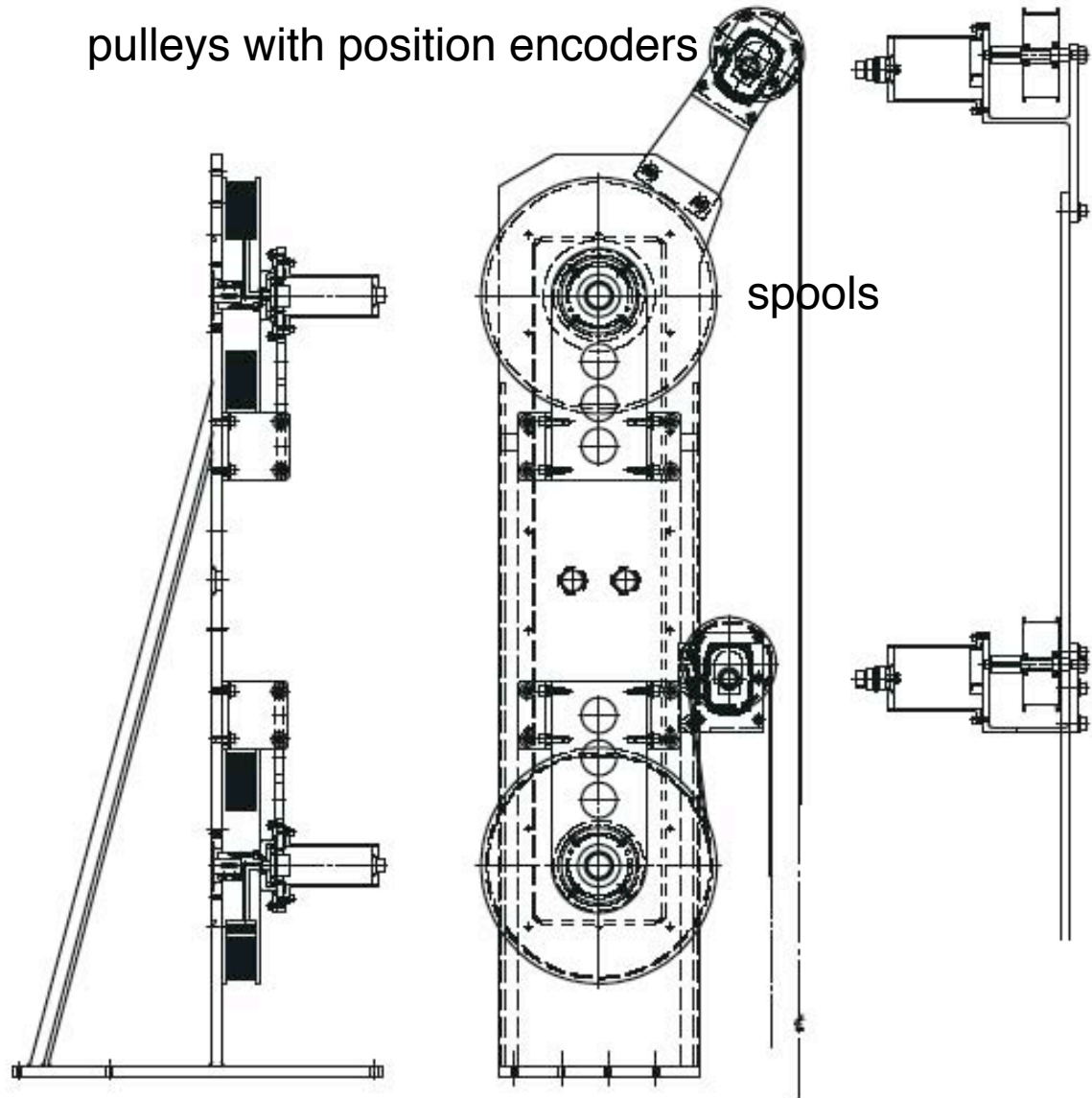
Tent Floor Plans



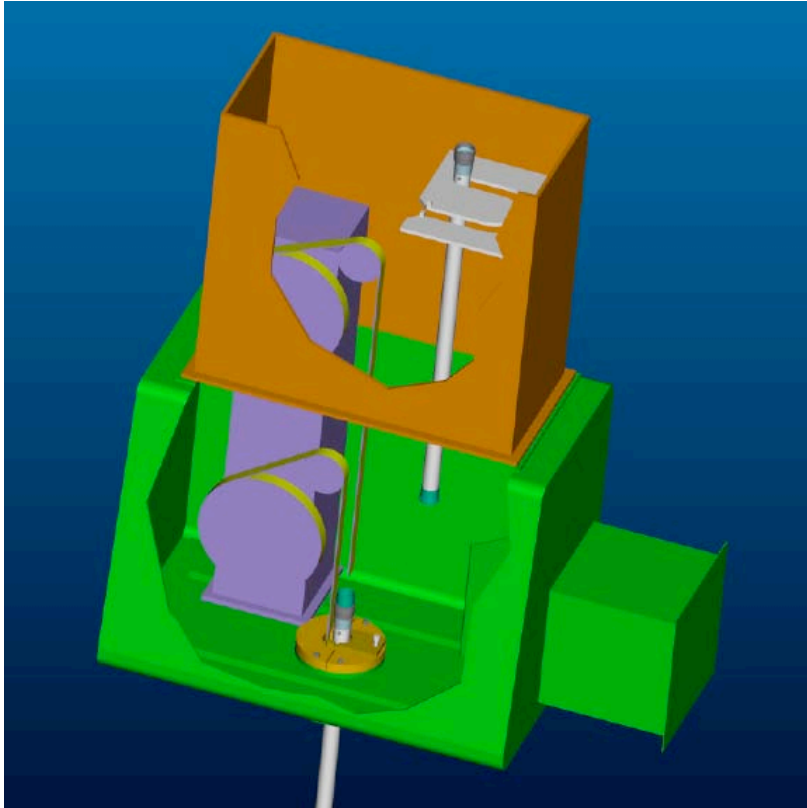
Motor Drive System



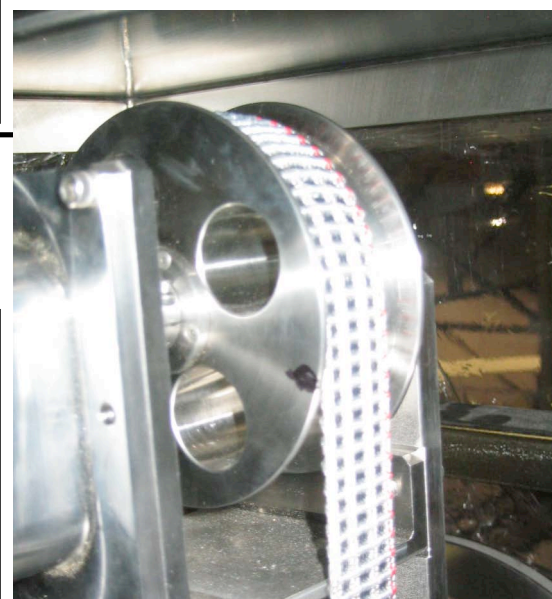
pulleys with position encoders



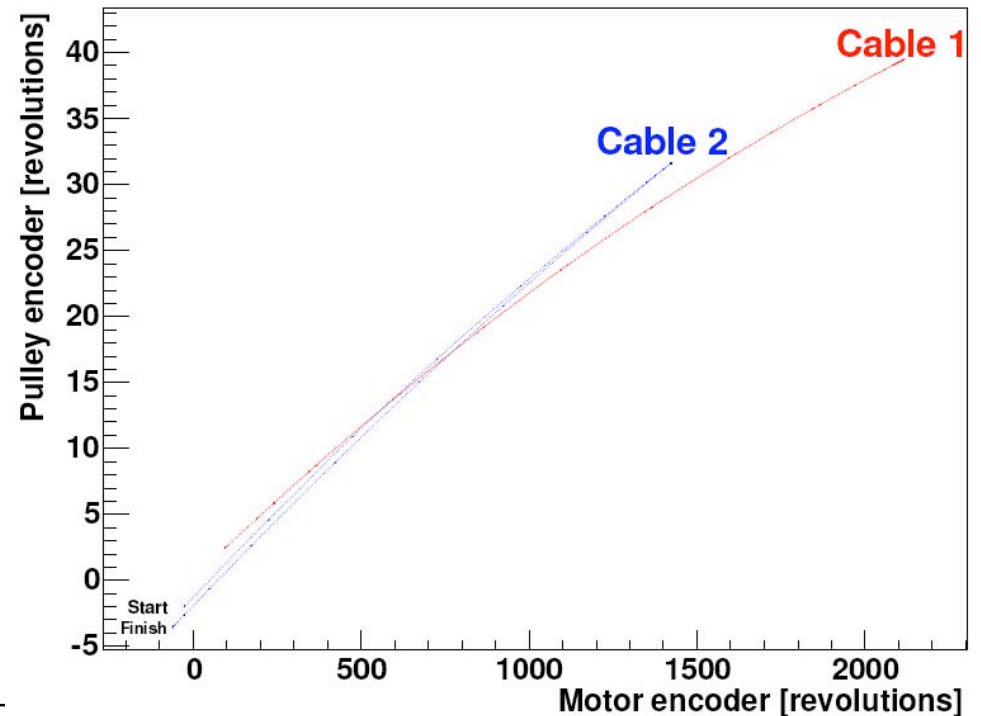
Glovebox System and Deployment Hardware



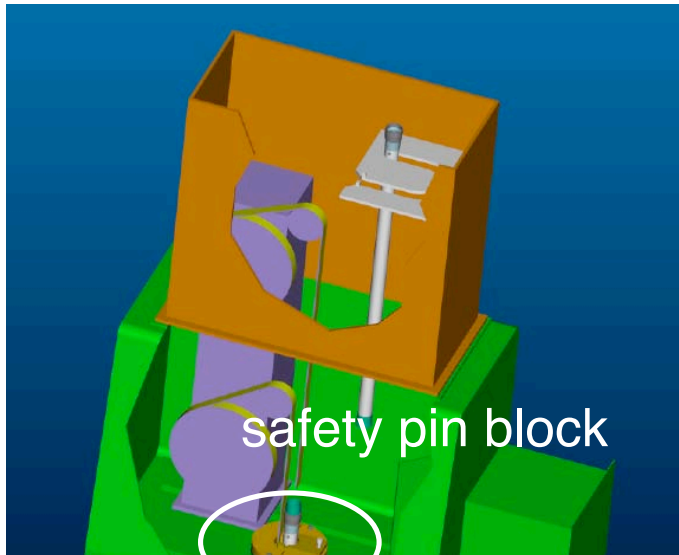
Encoder and Guide Pulleys



- cable 1 behaves as expected
- accuracy of encoder pulleys: < 0.5 cm
- curve fits well the cable length on spool
- cable 2 not used as much, memory effect from fabrication

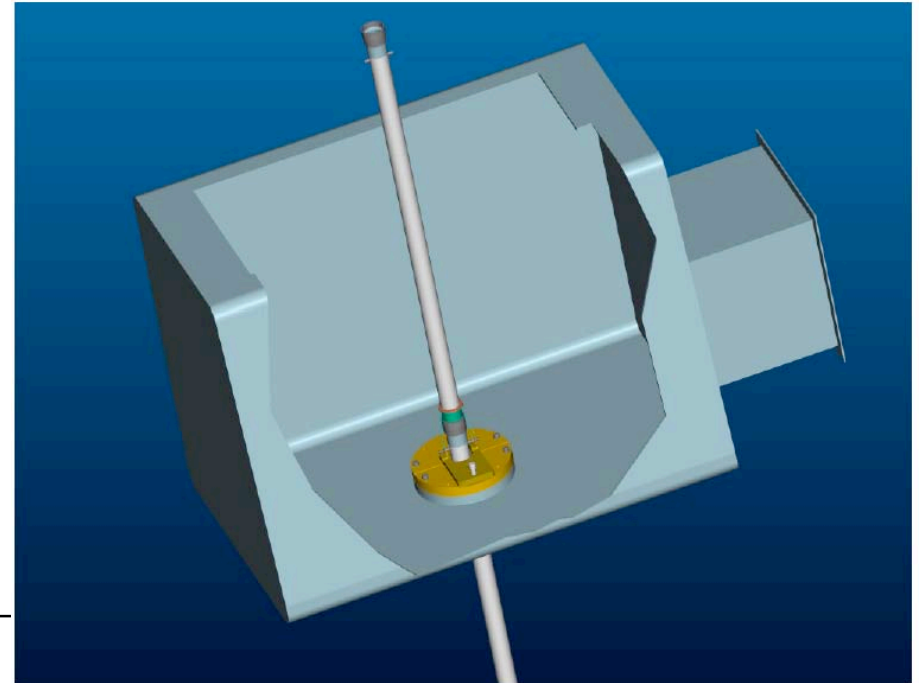
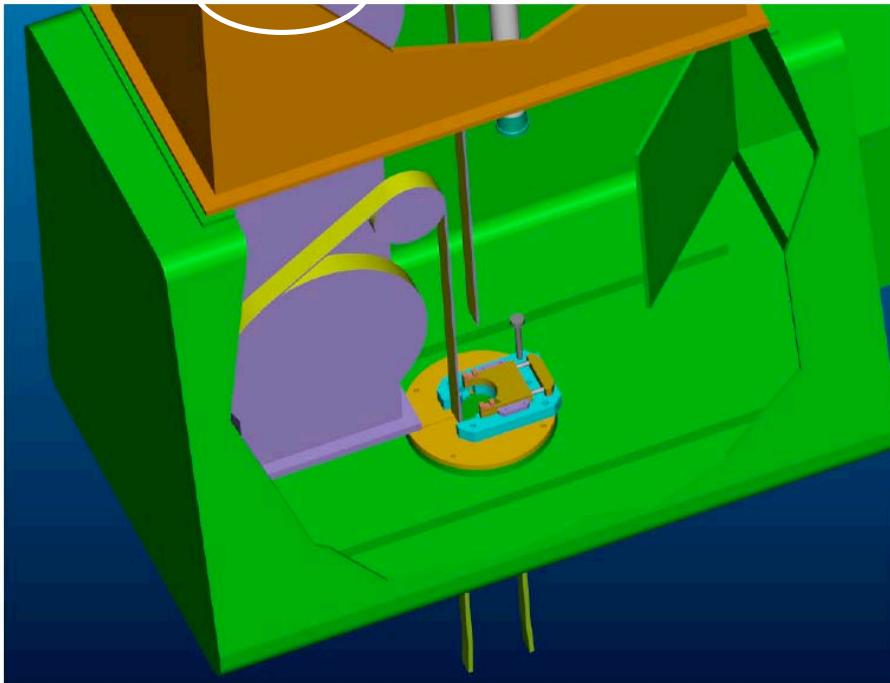


Safety Pin Block

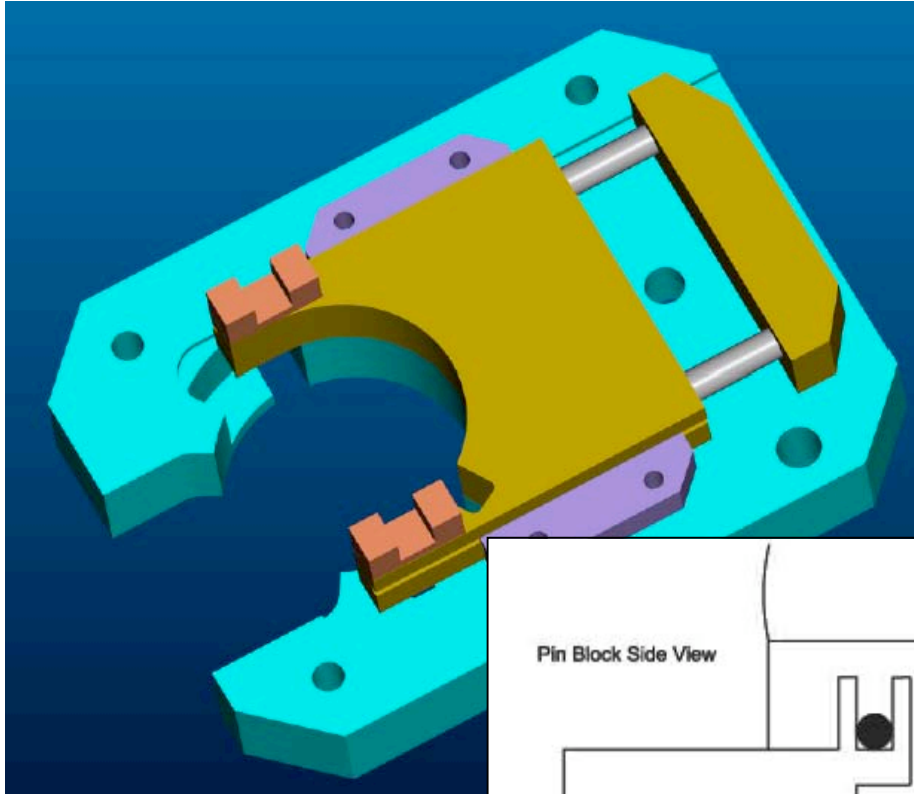


Purpose

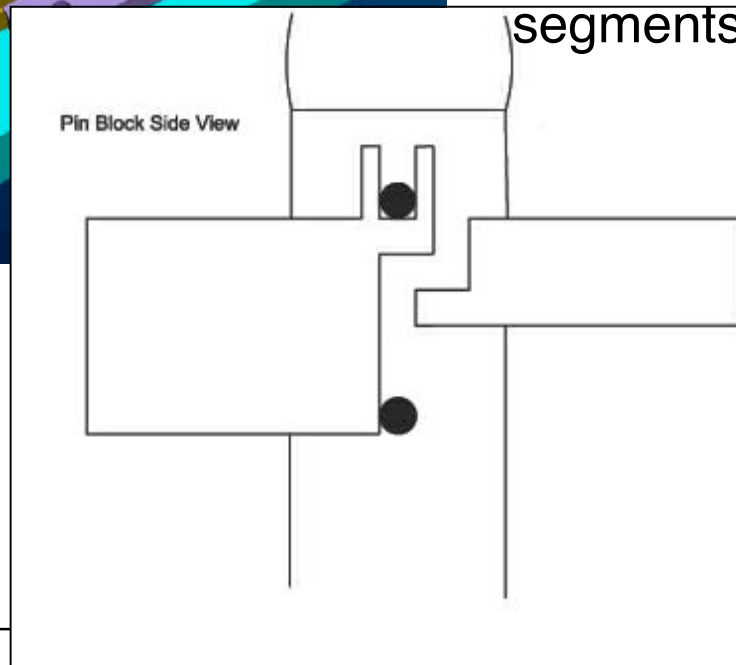
- I. Safety block between glovebox and detector.
- II. Used for assembly of pole.
- III. Allows easy retrieval of pole.



Safety Pin Block

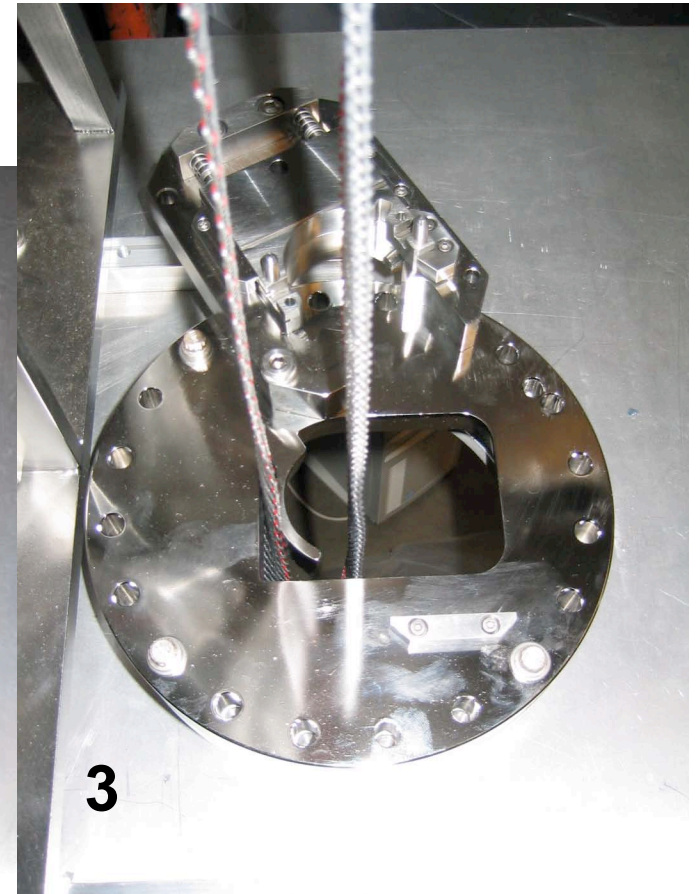
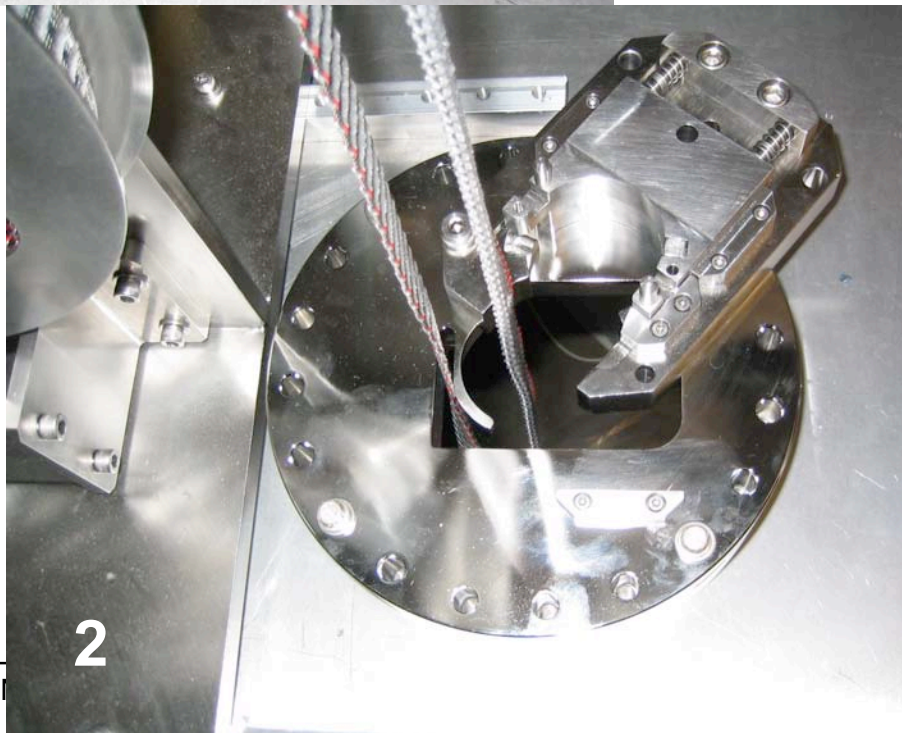
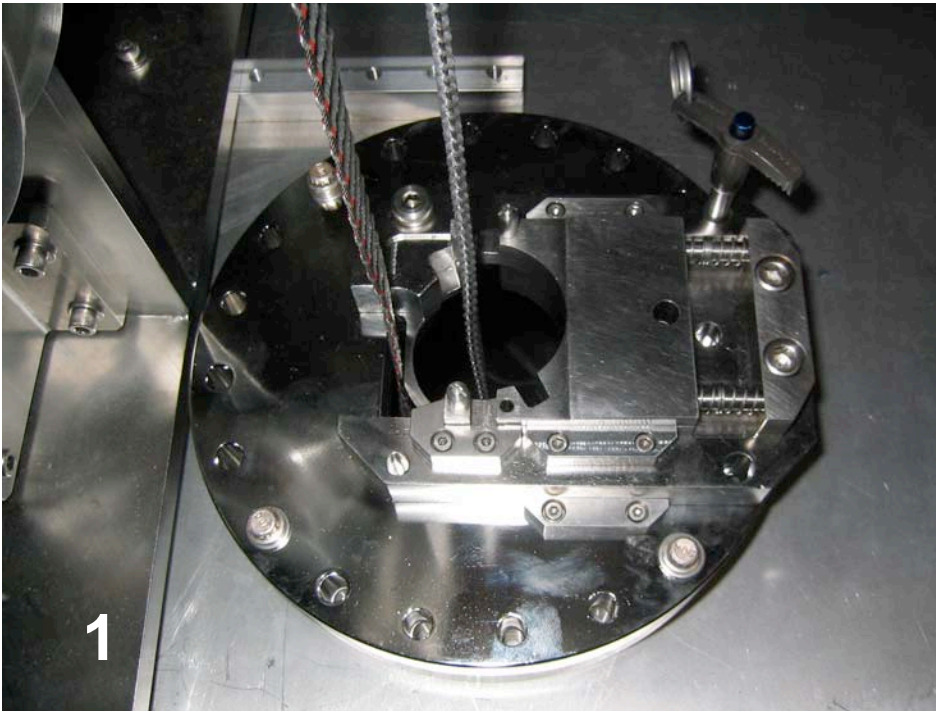


1. prevents pole segments from dropping into detector
2. operator needs to turn pole segment when engaged in safety pin block
3. sliding block allows easy retrieval of calibration pole segments

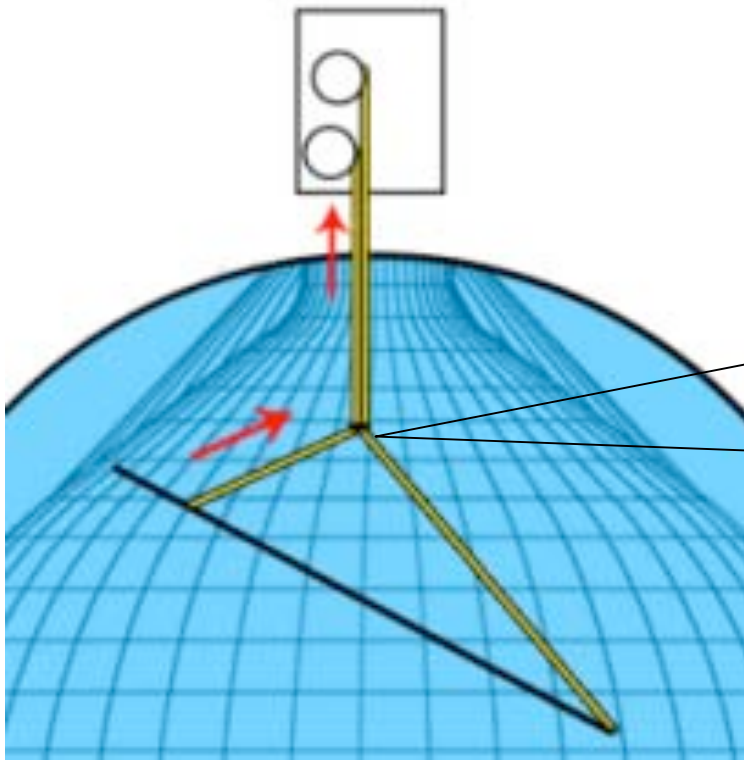


The New Pin Block

- mounted on conflat flange
- guides control cables
- rotates to allow pivot block to pass
- provides 3-step safety lock



Pivot Block



An essential part to control
motion of system

Fixed control cable

Movable control cable

Pivot Block - Functionality

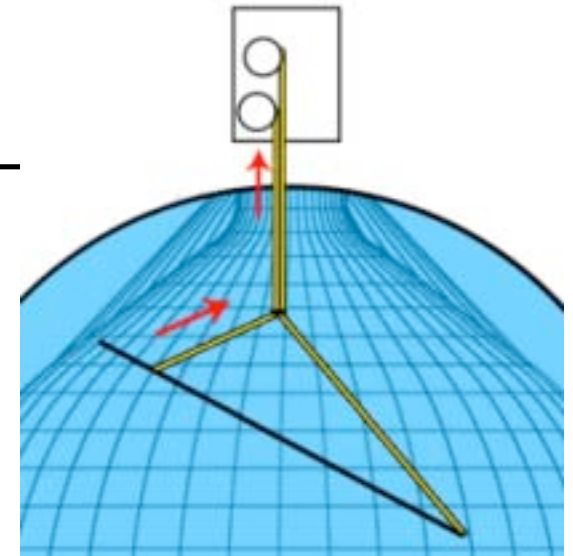
Locked

Disengaged



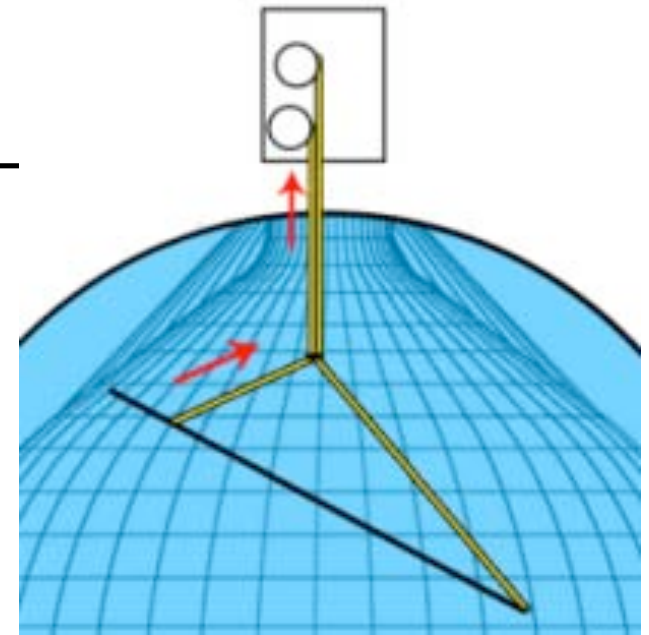
Pivot Block - Revisited

- consists of (1) pivot and (2) clamp
- uses cable clamp, no crimping
- adjustable positioning

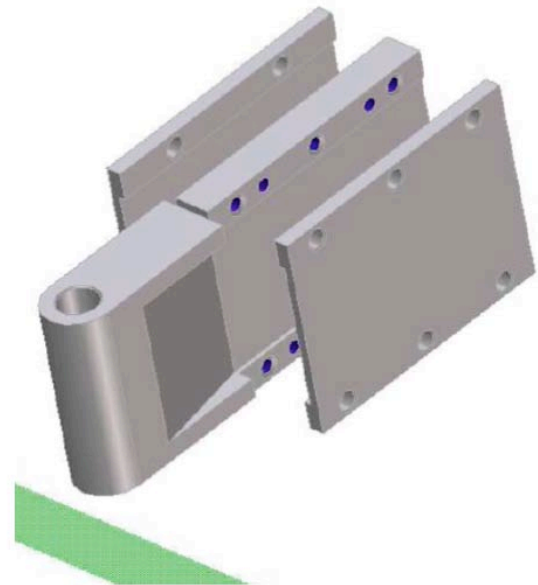


Cable Attachment

- modular
- allows easy replacement of cable
- greater stability and control

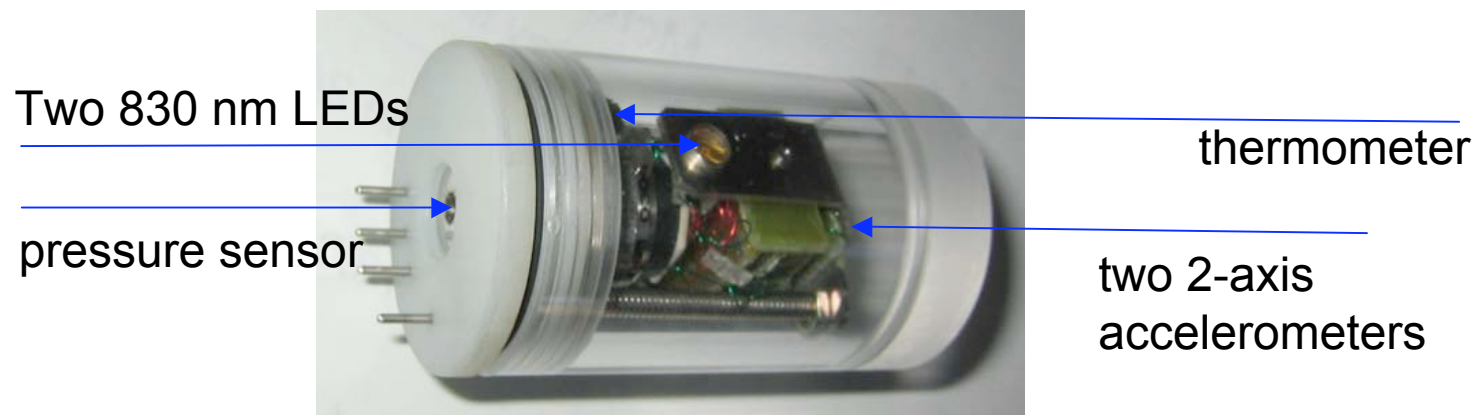
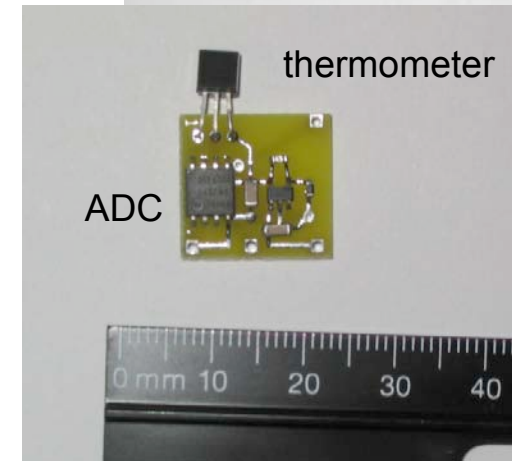
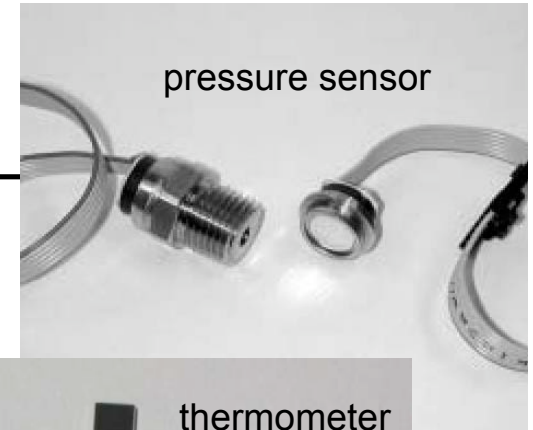


stainless cable clamp



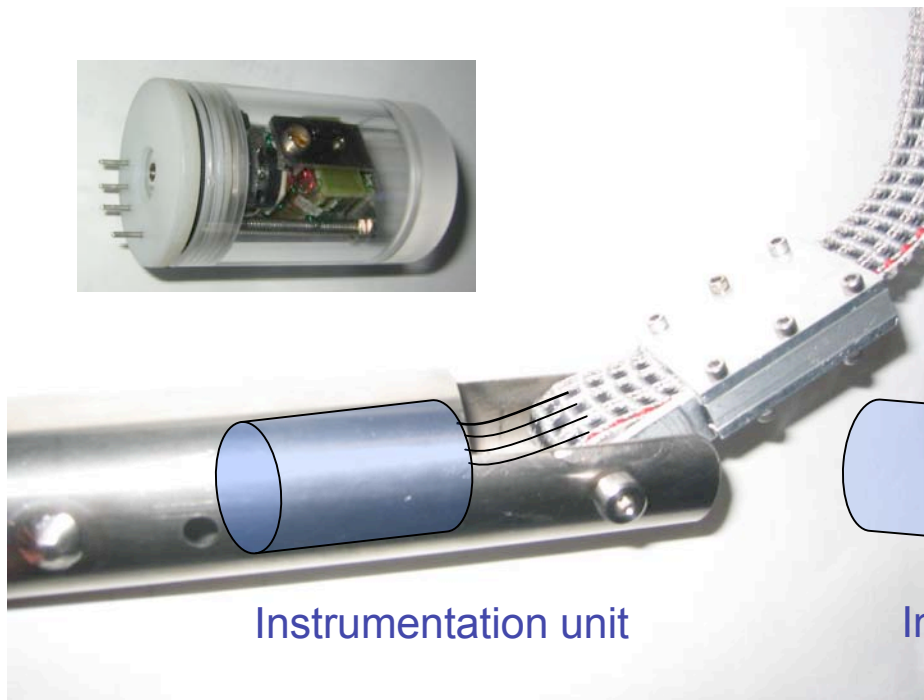
Instrumentation Unit

- prototype completely assembled, being tested
 - uses total of 3 wires in control cable
- 4 functions:
1. reads out pressure sensor
 2. controls LEDs
 3. measures temperature
 4. Inclinator and accelerometer



Electrical Connections and Breakout at Cable Ends

Top Cable End



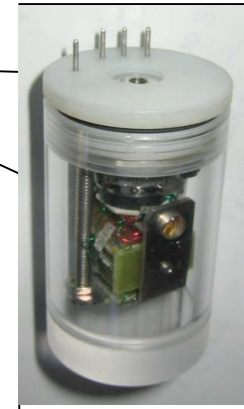
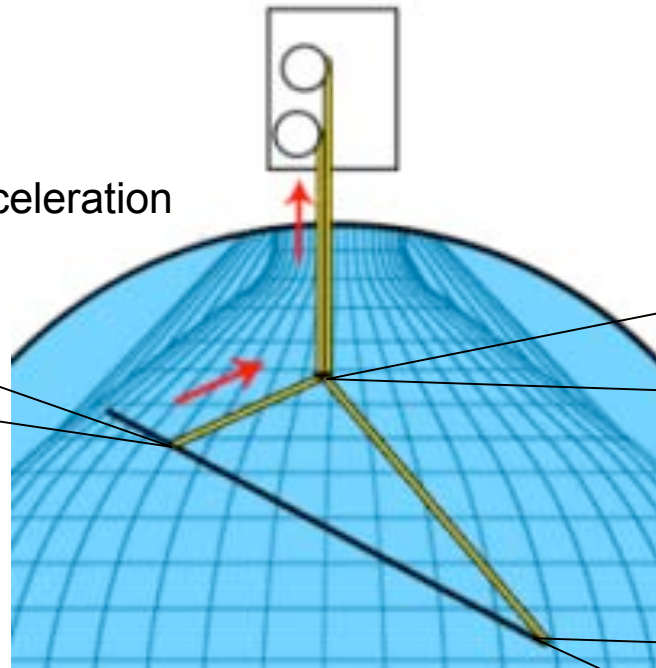
Lower Cable End



Instrumentation of the 4pi System

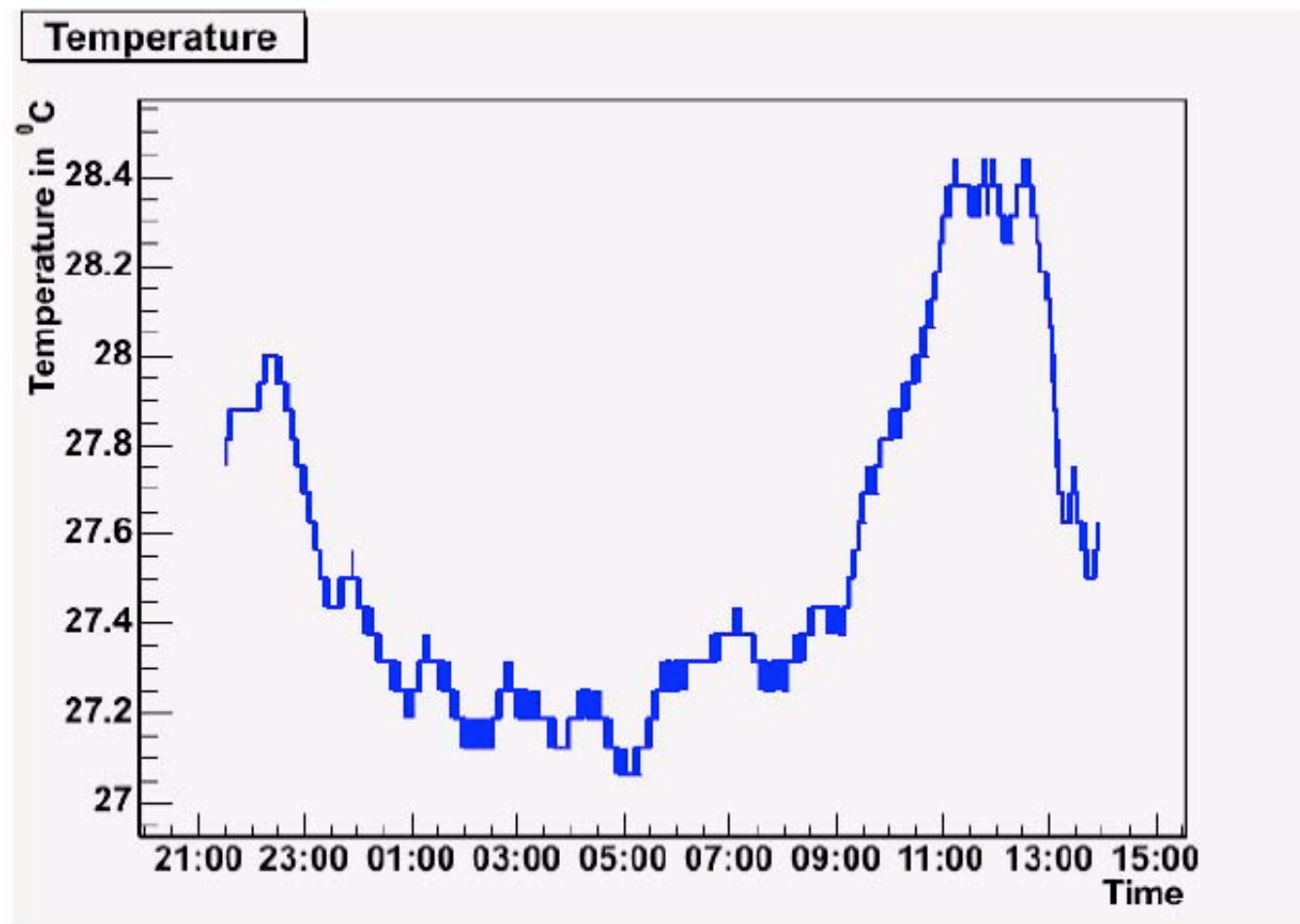


- temperature
- pressure
- inclination, acceleration
- 830 nm LED



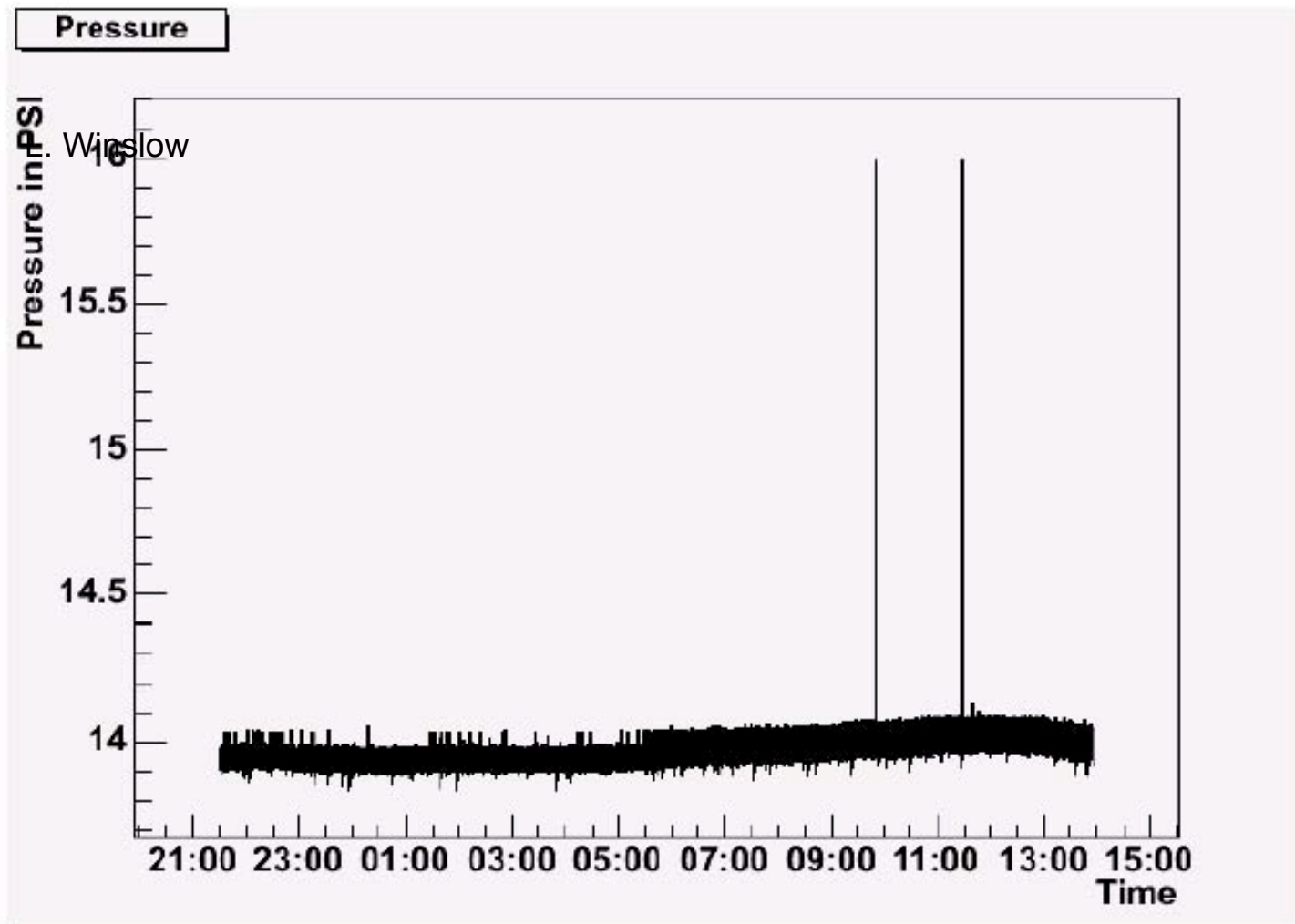
Redundant position information:

1. **cable length** (encoder pulleys, motor counts) < 0.5 cm
2. **depth** (3 pressure sensors) $< \sim 1$ cm
3. **inclination** of calibration pole (accelerometers)
4. **CCD imaging** of IR LEDs



L. Winslow

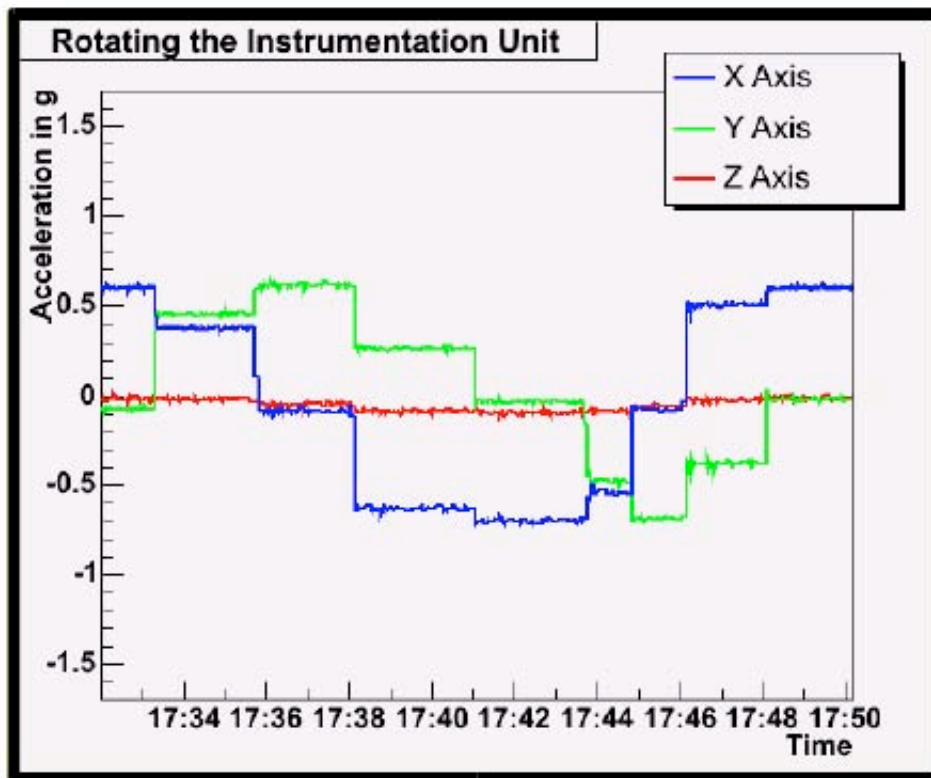
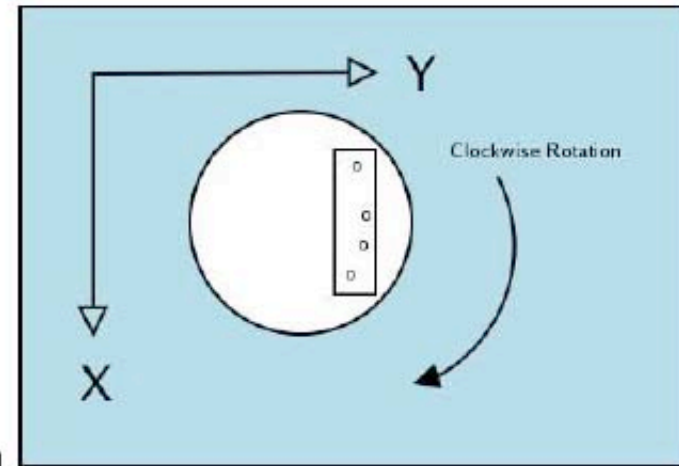
Temperature in my office on Thursday Night.
(Unit was sitting in insulation on top of its power supply.)



L. Winslow

Barometric Pressure in my office Thursday Night
→ Needs Calibration for resistor variations.

4Pi Instrumentation Unit

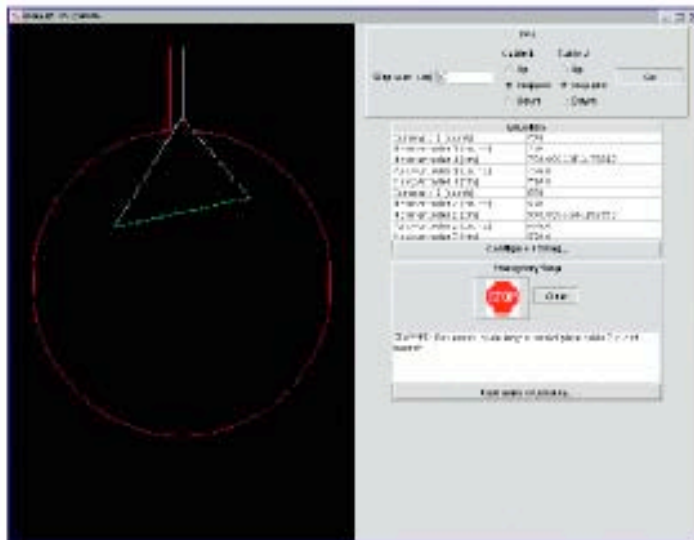


Follow the direction of gravity relative to the unit as you rotate it.

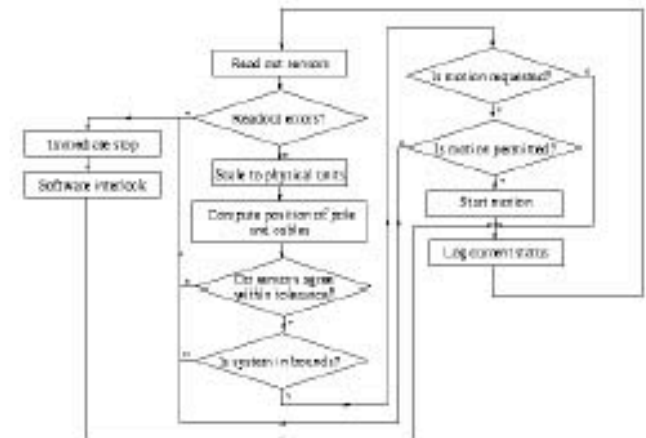
L. Winslow

Control Software

Display program



Control program



Parameters
(Java RMI)

- Separation of Display and Control program
 - Each program can be separately restarted if needed
 - Each step has to be pre-approved before motion occurs
 - Replay capability to analyze failures

F. Gray, P. Decowski

Software Organization

- 4Pi control: three sets of Java classes
 - Hardware interactions
 - Human operator interactions
 - Middleware
- Control software available in CVS
 - Module KamLAND/FourPi

F. Gray, P. Decowski

Materials Qualifications

Principles and Guidelines

- All materials are being tested:
 - titanium
 - stainless
 - teflon
 - nylon
 - lucite
- Samples from any material is tested as a specific batch out of production.
- All parts that enter the inner detector will be soak tested after final assembly, testing, and cleaning.
 - cables
 - calibration pole
 - instrumentation unit
 - pivot block
- Prior to testing and deployment, all materials and containers are being cleaned at LBNL, as per UHV standards

(details in document at <http://kmheeger.lbl.gov/kamland/4pi/>)

Method of Analysis

- No visible peaks in majority of spectrum
- Summed over channels and subtracted background
- Peak width was calculated by using source calibration free fit gauss + p1 s.
- All errors are statistical

G. Keefer
C. Mauger

Results from On-Site Counting

Sample	LS mass[g]	Sample mass[g]	^{210}Pb [cpd]	^{226}Ra [cpd]	^{40}K [mBq]	^{208}Tl [mBq]	^{212}Pb [mBq]	^{214}Pb [mBq]	^{214}Bi [mBq]	^{228}Ac [mBq]
Nylon mono-filament cable part	71.129	0.0722	3.23±1.55	0.934±1.36	2.14±1.13	0.21±0.17	0.19±0.13	0.47±0.39	0.39±0.10	0.37±0.90
Titanium	77.869	5.415	4.90±1.13	2.12±1.05	1.40±0.73	0.10±0.11	0.08±0.10	0.30±0.27	0.29±0.75	0.44±0.67
Stainless Steel Cable Part	76.4	3.7167	1.57±1.50	-0.50±1.43	4.10±1.26	0.11±0.16	0.18±0.14	0.88±0.43	0.29±1.06	0.08±0.94
Teflon Conductor	71.679	0.8051	1.55±1.56	0.95±1.61	2.39±1.08	0.21±0.18	0.11±0.13	0.50±0.46	1.34±1.32	- 0.61±0.93
Connector (motors, possible transducers)	79.889	25.3037	0.89±1.47	2.10±1.47	1.12±1.03	0.23±0.20	0.22±0.14	0.47±0.39	0.56±1.15	- 0.31±0.87
Delrin	73.202	4.059								
Blank	-----	-----	5.65±1.61	-0.53±1.45	1.92±1.07	0.24±0.17	- 0.03±0.14	0.44±0.21	0.63±1.19	- 0.19±0.87
Background	-----	-----								

Note: Delrin not used in current 4pi system.

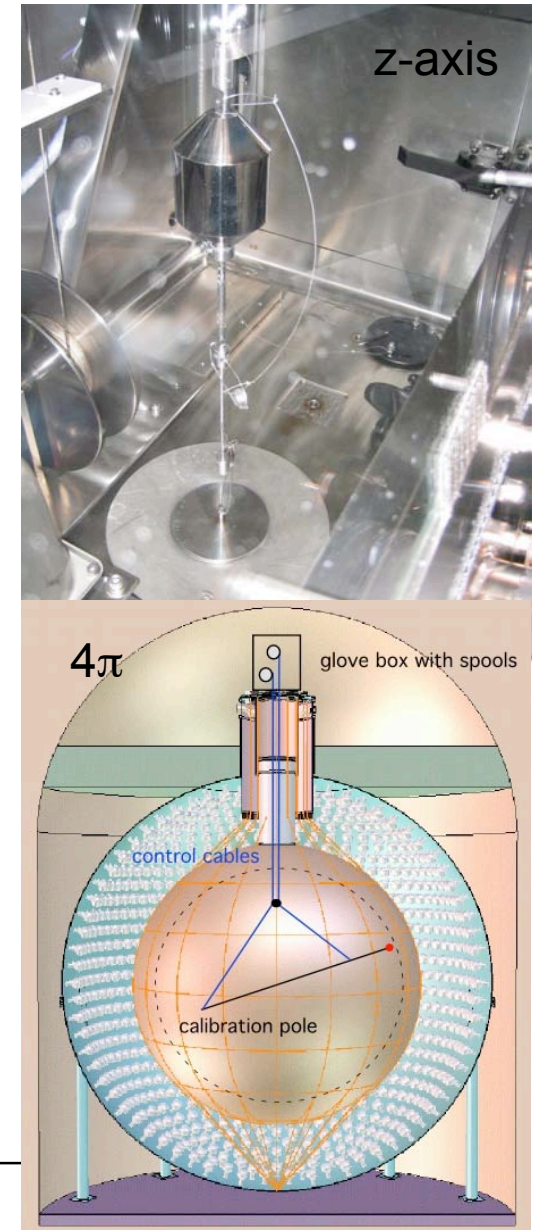
Source Shadowing Effects of the Deployment System

Question:

- What is the shadowing effect of the 4pi system?
- How do we compare data taken with the 4pi and z-axis systems?
- Can we correct for the shadowing effect in different deployment systems?

Proposal:

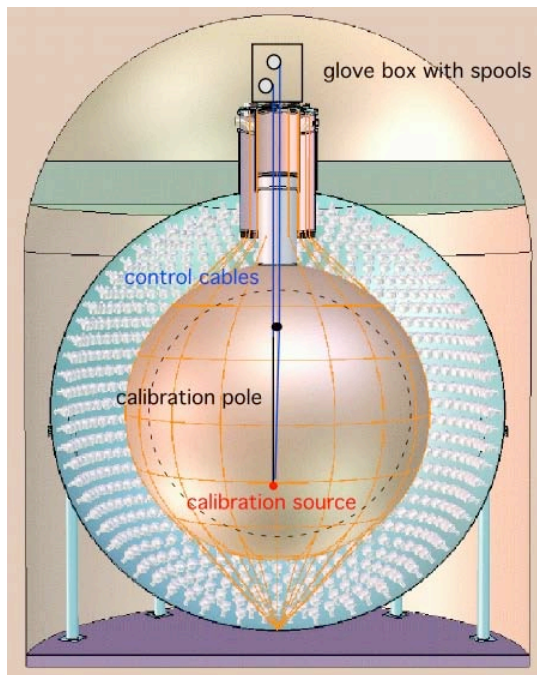
- Systematic study of source shadowing effects with z-axis system: Experimental study + simulations.
- Estimate and corrections of possible source-shadowing effects in 4pi system.



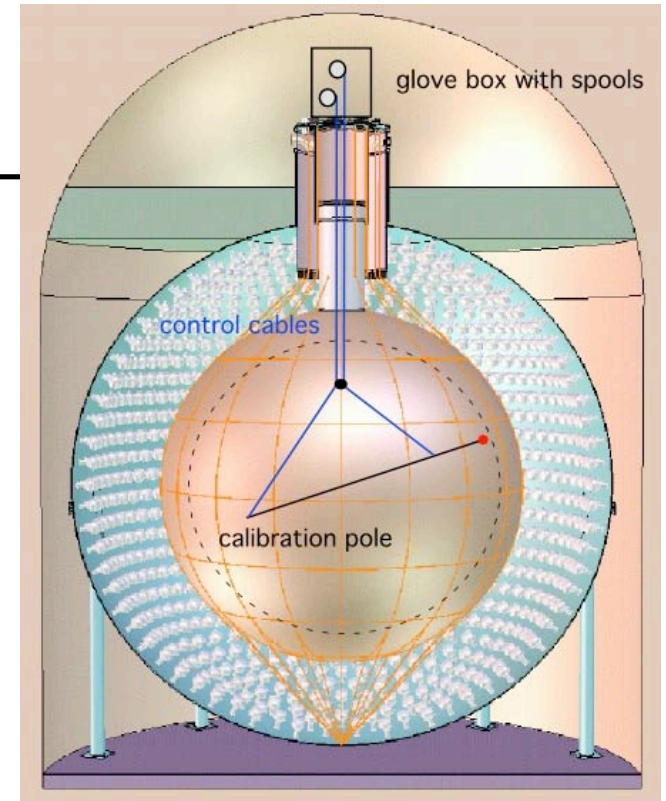
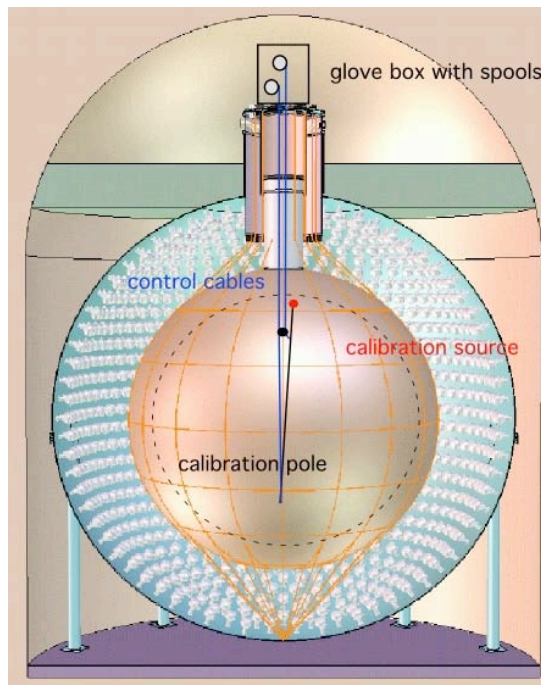
4π Full-Volume Calibration System

- Position dependent shadowing
- Calculate geometric shadowing effect

Minimum Shadowing



Maximum Shadowing



Z-axis System with Extra Shadow

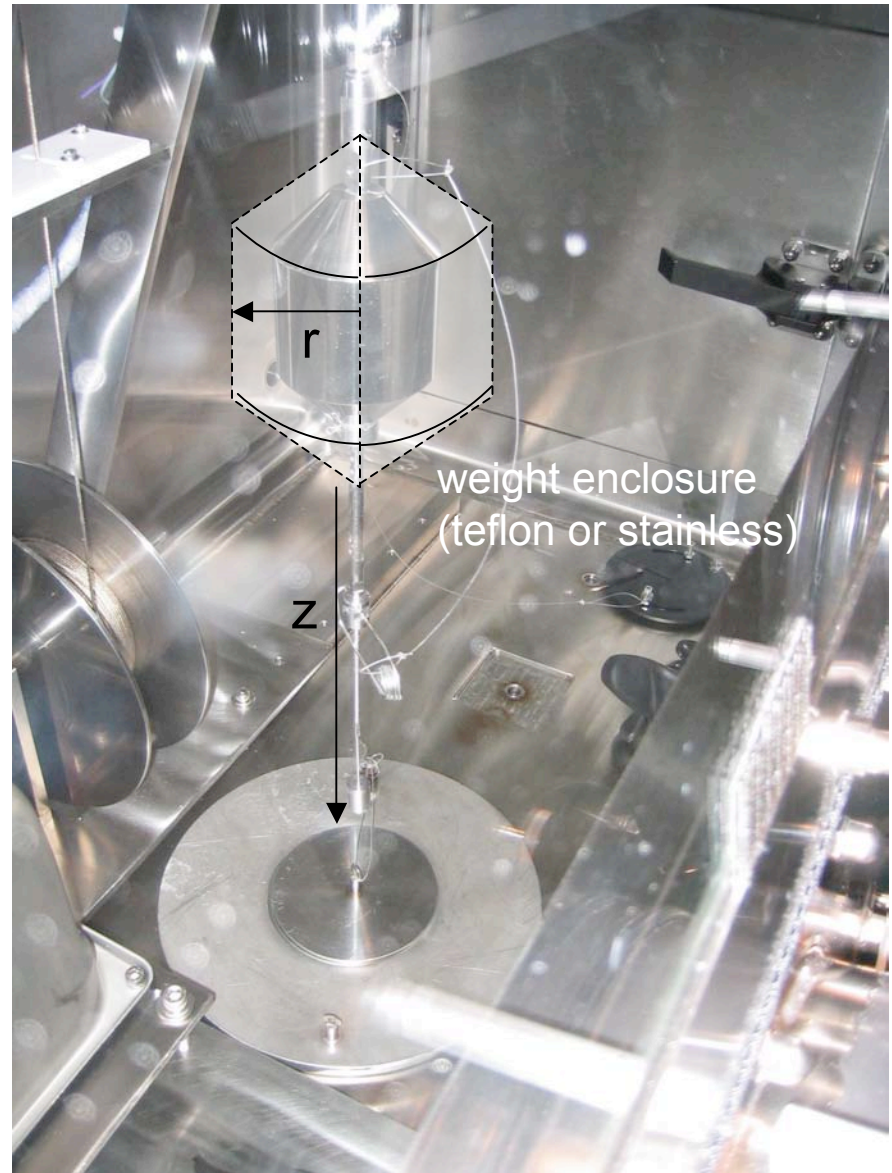
geometrical shadow of present
z-axis weight ~ 0.003

With enlarged z-axis weight of
radius r at distance z we can test
geometric shadowing:

r	z	Fractional Shadow $\pi r^2 / 4\pi z^2$
1.25	12	0.003 (present)
2"	10	0.01
2.5"	10	0.015
2.5"	8	0.025

weight enclosure:


- mounts in same position as z-axis weight
- compatible with LS (teflon or stainless)
- same shape \rightarrow scales shadowing effect



Getting There

How do we reach the installation of the 4pi system?

Critical Items, Manpower, and Timeline

- | | |
|---|---------|
| 1. Completion of mechanical work, fine-tuning system (LBNL) | Oct/Nov |
| 2. Deployment testing (LBNL + others welcome to join and visit) | Nov/Dec |
| 3. System review and demonstration (collaboration) | Nov/Dec |
| 4. Materials Certification (Alabama, Caltech, Mozumi, LBNL) | Oct-Dec |
| 5. Setting up cleanroom at KamLAND (LBNL, Mozumi) | Dec/Jan |
| 6. Installation and commissioning | Jan-Mar |
- 

Clean Handling of 4π System

At Berkeley

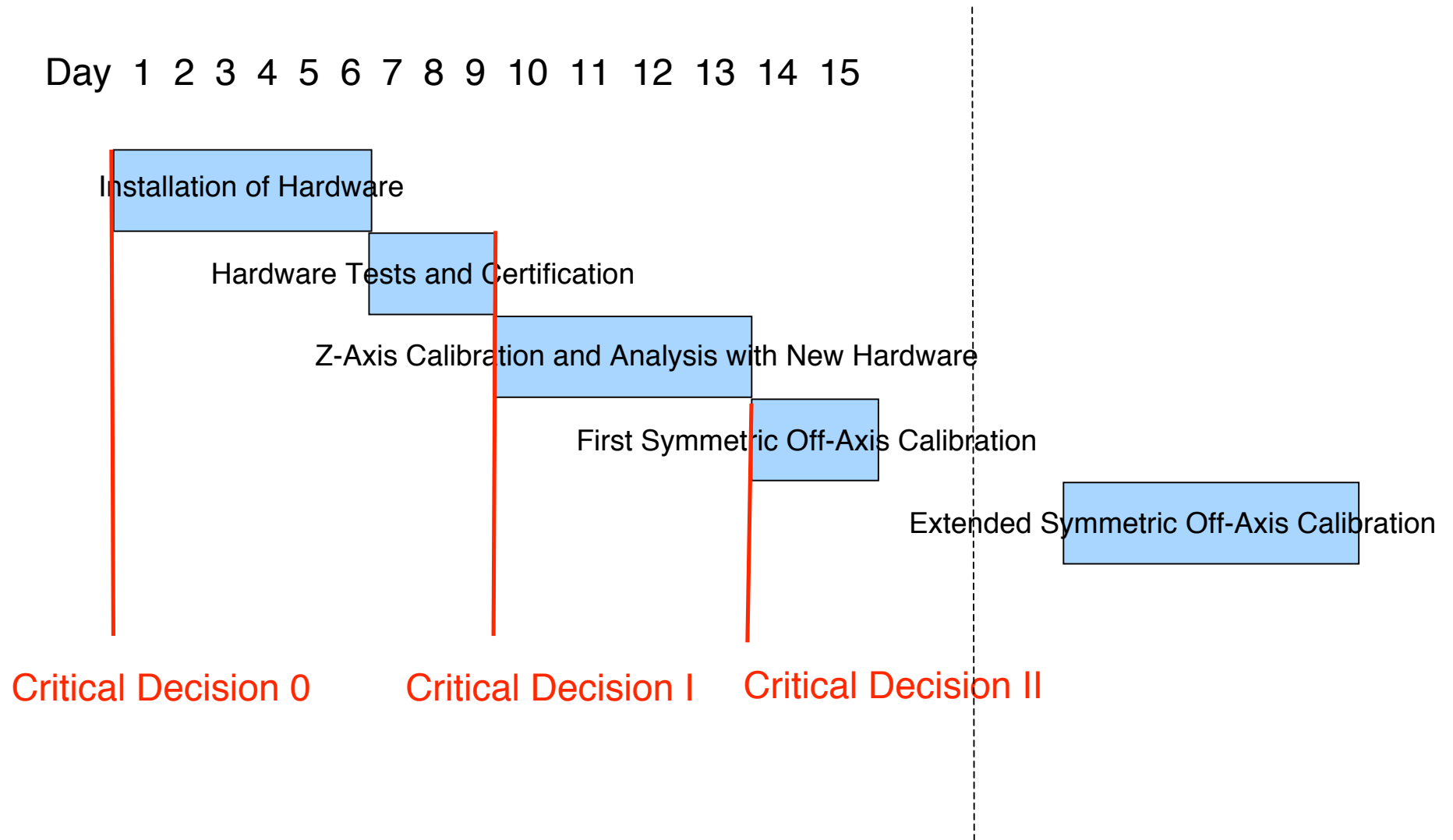
- Pre-assembly of UHV-cleaned components at Berkeley before shipment to KamLAND.
- Use existing cleanroom to soak test cleaned 4π components.

At KamLAND

- Installation of second, temporary cleanroom in dome area for assembly and test of 4π system before installation.
- Size requirements: $\sim 2 \times 3$ m



Commissioning Schedule



Commissioning Schedule

Commissioning and Data Taking

Day 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Installation of Hardware

Hardware Tests and Certification

Z-Axis Calibration and Analysis with New Hardware

First Symmetric Off-Axis Calibration

Extended Symmetric Off-Axis Calibration

- Don't expect full-volume calibrations to become routine calibrations.
- Goal is to obtain enough information about fiducial volume and detector response to reduce dominant systematic errors for the reactor analysis, and to allow us to make most precise determination of Δm_{12}^2 .

Summary of Present Status October 2004



<http://kmheeger.lbl.gov/kamland/4pi/>

